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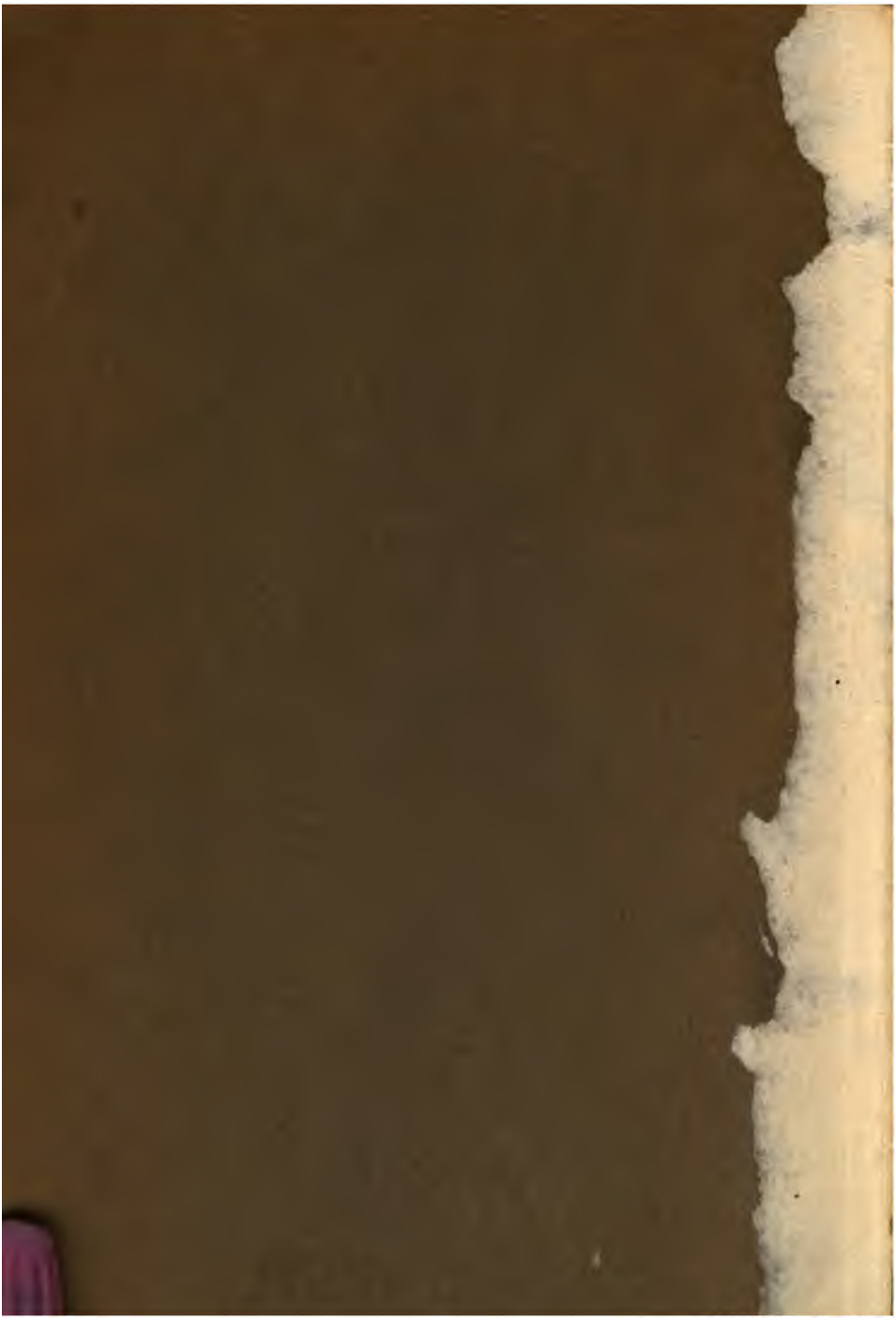

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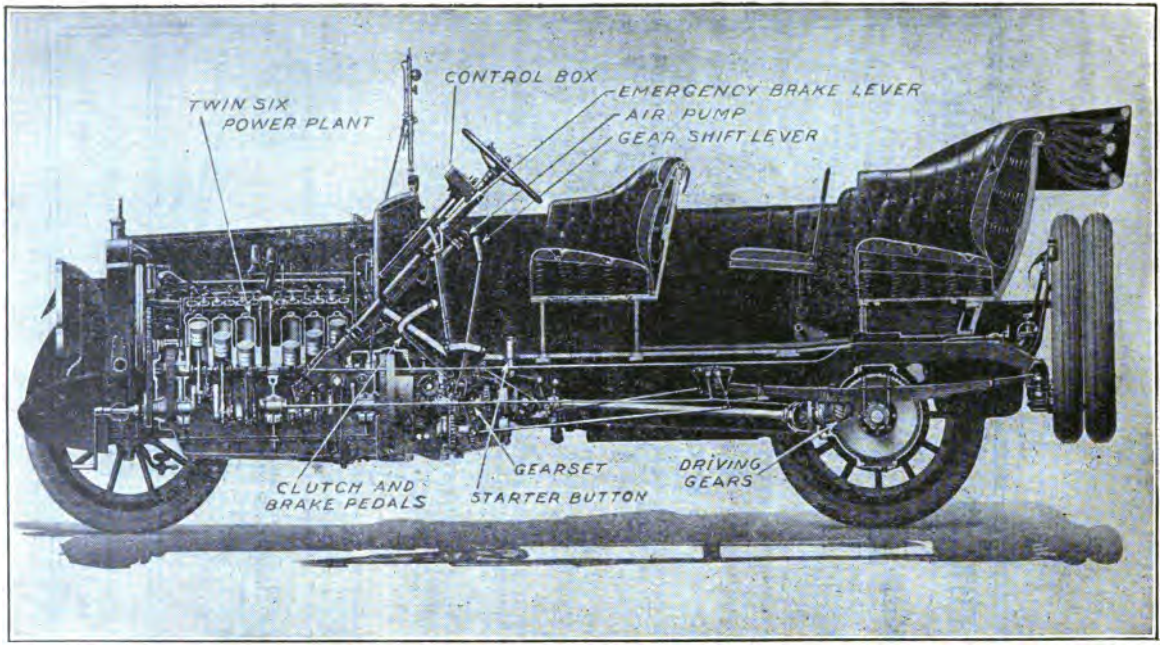

Part Sectional View of 1917 Packard "Twin Six" Automobile showing internal arrangement of Power Plant, Transmission Mechanism and Body.

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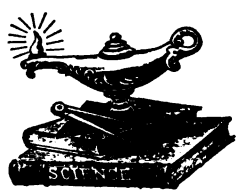

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NEW YORK

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INTRODUCTION

A wide, general editorial experience obtained through careful consideration of the needs of the average automobilist by the writer while technical editor for one of the leading motor-car journals, has shown that the modern motorist is always seeking for information that will enable him to run his car more intelligently. A number of primers, catechisms, handbooks and other literature of this nature have been prepared for educating the prospective or present owner or driver of an automobile, but all of these have been criticised because of various shortcomings, though some have been of great value.

They are seldom arranged in a logical manner and for the most part assume that those they try to teach are technically informed. One passes from a chapter on running gear parts directly to one on ignition and from that to one on car oiling or some other subject foreign to that previously considered. This arrangement makes it difficult for the average reader to get the utmost value from his reading. For the most part the illustrations are crude representations, often of imaginary mechanism, and it is seldom that the various essential points the author wishes to call attention to are indicated in any intelligible manner on the illustration.

The splendid reception accorded the writer's previous work "The Modern Gasoline Automobile" has been very gratifying. This work was written as a general treatise and no attempt was made to make it a primer or elementary work. So many motorists have written to the publishers commending the logical arrangement of the text and the clear accurate illustrations and so many suggestions have been received by the writer that he prepare a more simple and cheaper book arranged as a primer or textbook, that after considerable thought regarding the best method of presentation of fact in simple language, this treatise has been prepared. This is

complete in itself but can be supplemented to advantage by a general course of reading of the writer's previous work.

The arrangement of the subject matter in the form of lessons consisting of questions and answers has been followed to make the book suitable either as a home educator or as a textbook for use in schools. Every endeavor has been made to arrange the contents logically and the reader is brought progressively from one element of the car to the next relative part rather than in the spasmodic manner usually found in a work of this nature.

A number of the lessons were specially written for instructing classes by the writer when he was associated with one of the first automobile schools established in the United States. They were very successfully applied in teaching the mixed classes and intellects found in schools of this nature. These lessons have been simplified and brought up-to-date and have a much greater value to the student than when first prepared.

Entirely new illustrations have been made and there is no conflict in contents between this and the writer's other work. Either is a complete exposition of the subject, and this can be used to advantage in connection with that first published as a series of questions for review, or the other and more complete work may be used to supplement this after the reader has grasped the rudiments of automobile construction and management by studying the lessons in this treatise. The arrangement by lessons will be found of value to those teaching automobile classes and the work should prove as desirable as a textbook as it is as a self educator for those that cannot get their knowledge except by home study.

Attention is directed to the completeness of this work, which includes all late developments in automobile engineering. The exclusion of matter of purely academic value or of interest only from a historical point of view means that the space usually devoted to this easily obtained class of matter, which has long been public property, is devoted to a consideration of driving, maintenance and repair of automobiles, which is obviously of more value to the reader.

The illustrations have been selected with well defined objects in view and while simplified somewhat in instances in order to make

them more easily understood by the non-mechanical reader, they are as accurate as relates to proportion of parts as the best engineering drawings and all represent existing mechanisms which are in daily use. The important elements to which attention is directed in the text are clearly designated by arrows and named in the illustration, so the main object of making them intelligible has been attained without sacrificing correct proportion. Any suggestions from readers for improving this work and calling attention to errors, either of commission or omission, will be welcomed by the publisher and the author.

This treatise has been entirely revised and all new improvements in automobile engine and chassis design have been included. Attention is directed to the new lesson on electric starting and lighting systems.

VICTOR W. PAGÉ.

JANUARY, 1918.

SYNOPSIS OF LESSONS

LESSONS	PAGE
1—The Modern Gasoline Automobile and Its Principal Parts	17
2—Action of Two and Four Stroke Cycle Motors	37
3—Parts of Gasoline Motors and Their Functions	54
4—Fuels for Automobile Motors	105
5—Theory of Carburetion and Its Application	114
6—Types of Carburetors and Their Action	120
7—How Gas is Exploded in Cylinder to Produce Power	141
8—Parts of Ignition Systems and Their Purposes	147
9—Current Producers, Batteries, Dynamos and Magnetos	164
10—Low Tension Ignition Systems	189
11—High Tension Ignition Systems	195
12—Methods of Lubricating the Automobile Power Plant	210
13—Cooling the Gasoline Engine by Air	231
14—Typical Water Cooling Systems	240
15—Use of Clutch and Various Types Described	256
16—The Friction Transmission	272
17—The Individual Clutch Change Speed Gear	281
18—Action of Sliding Gear Transmissions	291
19—Methods of Drive to Rear Wheels	304
20—Differential Gear Construction and Operation	321
21—Rear Axle Types	329
22—Automobile Frames and Springs	341
23—The Steering Gear and Front Axle	355
24—Wheels, Rims and Tires	367
25—Automobile Bearings and Their Care	400
26—How to Start and Control Automobile Power Plants	425

LESSONS	PAGE
27—Methods of Speed Changing Outlined	433
28—Utility of Brakes and Their Use	448
29—General Driving Instructions	456
30—Oiling the Automobile Chassis	465
31—Road Troubles and Their Symptoms	487
32—Repairing Power Plant Group	494
33—Troubles with Power Transmission Parts	521
34—Chassis Troubles and Their Elimination	534
35—Fixing Tire Defects	545
36—Equipment and Accessories	565
37—Development of 1917 Auto Design	583
38—Electric Starting Systems	619
39—Useful Information	683

ACKNOWLEDGMENT

The writer wishes to acknowledge his indebtedness to a number of the leading automobile and parts manufacturers who furnished instruction books and photographs from which a number of the illustrations used were taken and which also offered valuable suggestions for treatment of this subject. While in nearly all cases credit is given in connection with illustration to the user or maker of the construction shown, general credit is due to the following manufacturers whose co-operation has made the production of a complete and authoritative work possible:

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LESSON ONE

THE MODERN GASOLINE AUTOMOBILE AND ITS PRINCIPAL PARTS

Q. What is an automobile?

A. Any form of wheeled conveyance propelled by a prime mover carried by it as an integral part of its mechanism, is an automobile. This term, however, is usually applied only to those forms of self-propelling vehicles designed to replace pleasure vehicles or trucks formerly drawn by horses. The steam roller, gas traction engine, steam locomotive, and various other forms of self-propelling machinery are not included in this classification.

Q. Name the three principal types of automobile.

A. Three forms of automobiles have been generally used, these being termed steam, electric or gasoline, according to the nature of their power plant. Forms of cars propelled by liquid air or compressed air have been tried but found unsatisfactory.

Q. What are the advantages of steam power?

A. The most important advantage of the steam engine as an automobile power plant, is that it is extremely flexible and is capable of delivering power which augments directly as the amount of steam admitted to the cylinders increases. All functions of the starting, stopping, reversing and speed changing may be obtained directly by throttle control. When more power is needed, as in hill climbing, the throttle is opened wider and more steam is admitted from the boiler to the cylinders, thus directly increasing the engine power. The steam automobile has disadvantages that offset the good features. Among these may be mentioned difficulty in starting promptly, as firing up is necessary in order to generate sufficient steam to run the engine; use of naked flame under the boiler which

introduces an undesirable element of danger from fire; constant attention to air, water, and fuel pumps; necessity of maintaining proper water level in boiler at all times; frequent replenishing of water supply which lasts but 20 miles as a rule, and excessive use of fuel. It will be seen that while the steam car is simpler to control than that propelled by gas power, there are so many things to watch that it requires constant attention on the part of the operator to keep the car running as it should.

Q. What are the advantages of the electric car?

A. The electric motor offers many advantages as a source of power for automobile propulsion. It is flexible and as easily controlled as a steam engine, because the electric energy used is drawn from an exterior source or storage battery just as the steam is drawn from a container or boiler where it is generated and stored under pressure. The power of the electric motor may be varied by altering the amount of electricity supplied to the windings. The electric automobile can be started, stopped, reversed, and various changes of speed obtained by the simple movement of a controller lever. The electric automobile is quiet, clean, easy riding, and especially adapted for use of women and children.

It is lacking in capacity, however, and has a well defined radius of action which is determined by the endurance of the storage battery which supplies the electricity. After an electric automobile is operated for a period equal to traveling a distance of 60 to 100 miles, depending upon the type, the batteries must be re-charged. This means that the electric automobile can only be used where proper charging facilities are available, which practically confines its use to the larger cities and towns and their suburbs. The electric automobile is not suitable for touring, and if run at its maximum speed for any length of time, the batteries are soon exhausted.

Q. What are the advantages of gas power?

A. The internal combustion or gasoline engine, as it is commonly called, because of the fuel generally used, has some disadvantages when compared to steam and electric power, but its many marked advantages make it superior to either of these types. A gas engine may be easily started by a simple quarter turn of the starting crank

when in proper condition, and is as easily controlled after it is set in motion as either the steam or electric motor. Modern gasoline automobile engines have great flexibility, and have a range of speed from 150 to 1,200 or more revolutions per minute, by simple movement of the spark and throttle control levers.

Once the gasoline engine is set in motion, it requires no more attention from the operator, and it will continue to run as long as the fuel supply, lubricating oil, and electrical ignition will hold out. Its range or touring radius is not limited by conditions which make it necessary to frequently replenish the supply of water, as is the case with the steam engine, and it is independent of the central charging station on which the electric automobile depends. It will carry fuel enough in a tank of small size so it is possible to go several hundred miles without a stop, and then this is only a stop of a few minutes duration or just long enough to refill the gasoline and oil tanks.

The internal combustion motor is the most economical form to operate, and as a rule, automobiles equipped with this form of power require less attention than either steam or electric automobiles. Some of the disadvantages advanced against the gasoline power plant are: lack of overload capacity which necessitates the use of change speed gears; inability to reverse engine, which means that reversing gearing is necessary to allow the automobile to run backward; inability to start engine under load, which means that a separate clutching mechanism is needed so the motor may be started independent of the vehicle and to permit it to run fast enough to develop its full power before the car is started. Electric motors and steam engines start as soon as the automobile to which they are fitted does, and as no clutch is necessary, they may be directly connected to the driving wheels by some form of positive gearing. Owing to its lack of overload capacity, reduction gearing must be used whenever a gasoline car is made to climb a steep hill, whereas the power of the electric or steam motor may be increased by permitting more energy to flow from the container where it is stored under pressure to the motor, thus no change speed gears are necessary on these types of vehicles. The disadvantages mentioned are more apparent than real, as with the highly developed form of gasoline engines of the present day, there is no need of constant gear changing or speed

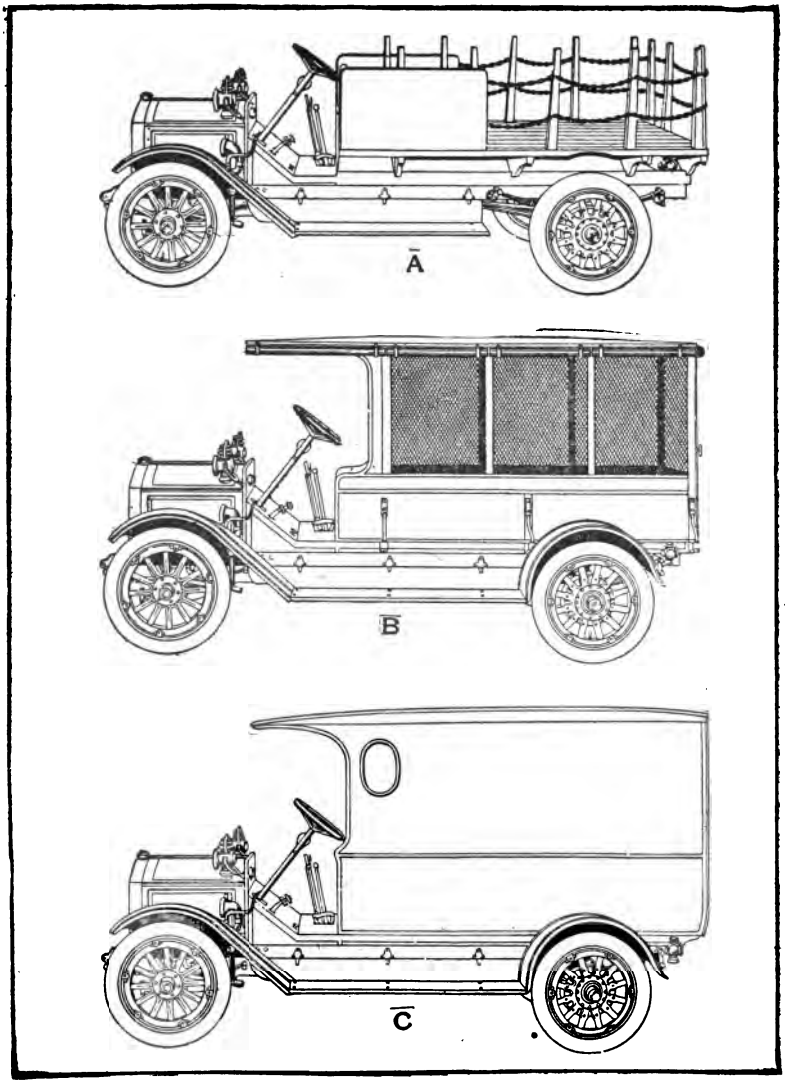


Fig. 1.—Chassis of the Pleasure Car Type Fitted With Various Forms of Delivery Bodies. A—Stake Platform Body. B—Wire Side Delivery. C—Panel Side Delivery.

shifting, and practically all the variations of speed that are desired on average highways may be obtained by simply manipulating the throttle lever which supplies more gas to the engine. The speed changing lever is left in its direct drive position and is not moved to the lower gear ratio except when starting the car or when ascending steep grades. The modern gasoline automobile is just as suitable for city work as either the steam or electric cars and is much superior as a touring conveyance.

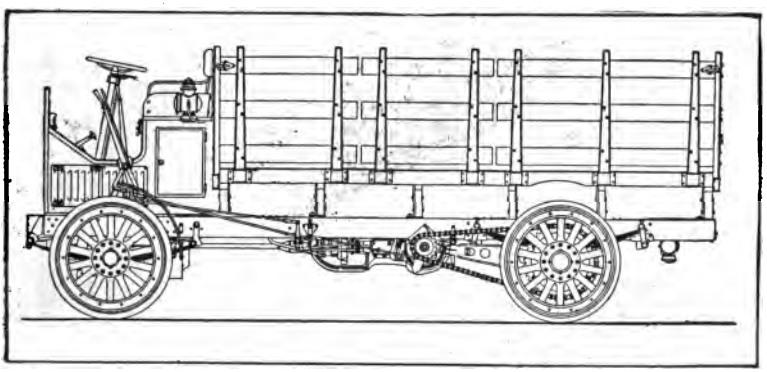


Fig. 2.—Side View of Typical Heavy Truck Design With Power Plant Placed Under Operator's Seat.

Q. Into what classes may automobiles be divided?

A. The two main classes of automobiles are pleasure vehicles and commercia cars.

Q. How do they differ from each other?

A. Pleasure cars generally are built for high speed and are much lighter than the commercial vehicles which must carry heavy loads. In a pleasure car as a rule, everything is sacrificed to speed and comfort. In a commercial vehicle, the parts are large and substantial and everything is designed with a view to maximum carrying capacity and minimum operating expense. The parts of automobiles are the same in general principle, whether used in a touring car or truck, except that they are made heavier, and of greater strength when used in the vehicle carrying the greatest loads. Pleasure cars

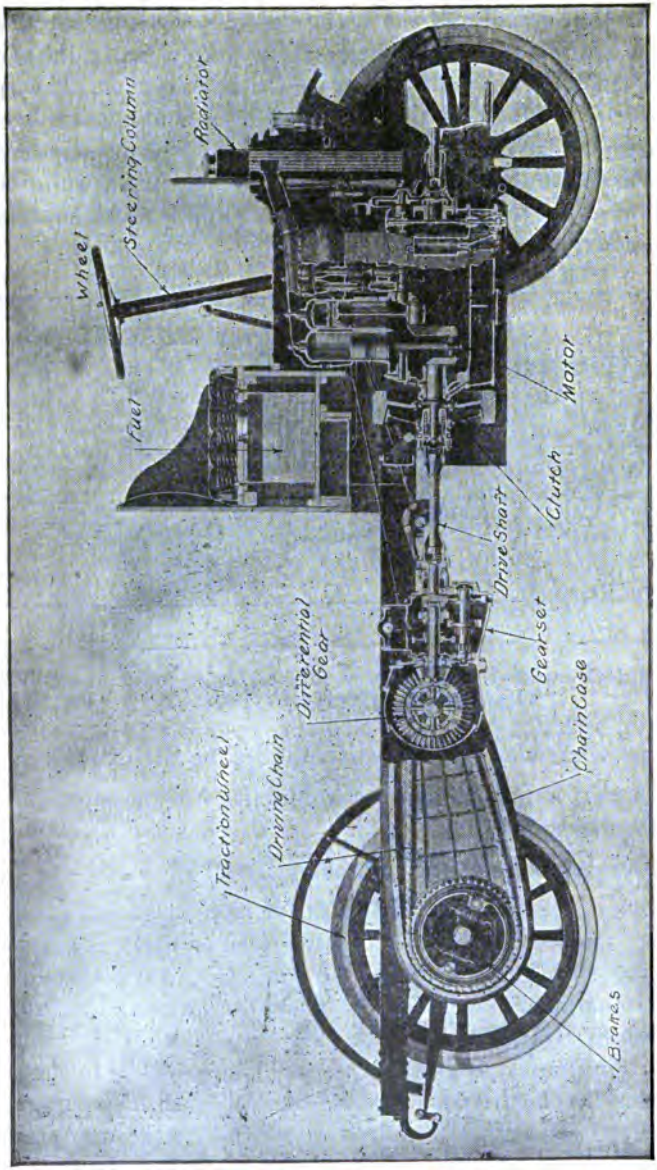


Fig. 3.—Sectional View of Natco Truck Chassis, Outlining Disposition of Important Chassis Components and Their Relation to Each Other.

are usually mounted on pneumatic tires, as air filled tires are called, while motor trucks which travel at slower speeds use solid rubber tires.

Motor trucks may be divided into two classes: those which utilize chassis patterned after pleasure types, but fitted with delivery bodies, as shown at Fig. 1, and those types of which a typical example is shown at Fig. 2, in which the motor is carried under the driver's seat and where the general design is such that the chassis can be used only for commercial purposes. There are classes of commercial cars, such as taxicabs, light delivery wagons, ambulances and vehicles of this nature, which are practically pleasure car chassis fitted with forms of bodies adapting it to a commercial use.

Q. What are the essential elements of the automobile?

A. The principal parts of automobiles are shown at Figs. 3, 4, 5, these outlining the chassis of pleasure cars and a typical truck. The foundation for the entire mechanism is the frame, which is attached to and supported by springs which are bolted to the axles on which the wheels are mounted. The power plant, which consists of the gasoline engine and a number of other parts, is usually carried at the front end of the frame, where it is housed under a hood, or in a special compartment under the body where it can be easily reached.

The clutch and gear set form part of the transmission system, as does the chain or propeller shaft used to transmit the engine power from the change speed gearing to the rear axle. A steering gear by which the direction of car is controlled and levers for shifting the change speed gears, for controlling the brake and for operating the spark and throttle of the engine, complete the chassis assembly. An automobile may be said to consist of the following main groups: the power plant; the clutch and change speed gearing; the power transmission system; the supporting frame and springs; the axle and wheels; the controlling elements; and the load carrying or body member. (Figs. 4 and 5.)

Q. What is the function of the power plant?

A. The purpose of the power plant is to generate enough power so that when this is transmitted to the rear wheels thru the medium of suitable reduction gearing, it will propel the vehicle.

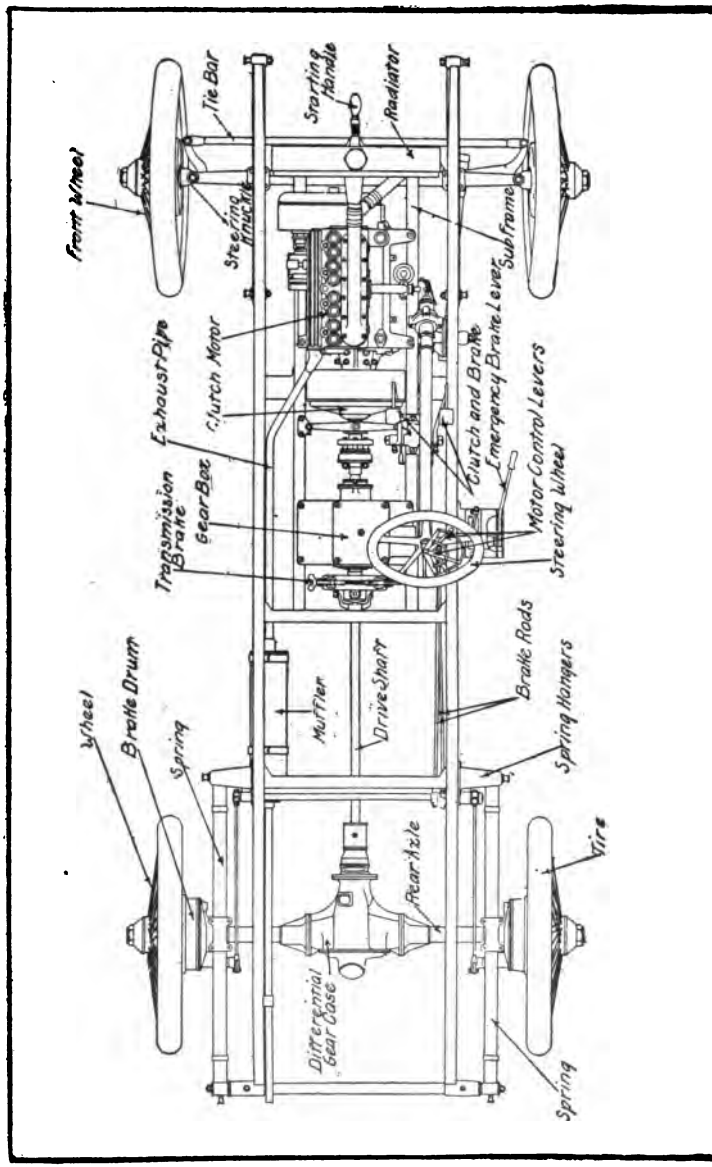


Fig. 4.—Plan View of Typical Modern Pleasure Car Chassis With Important Components Indicated.

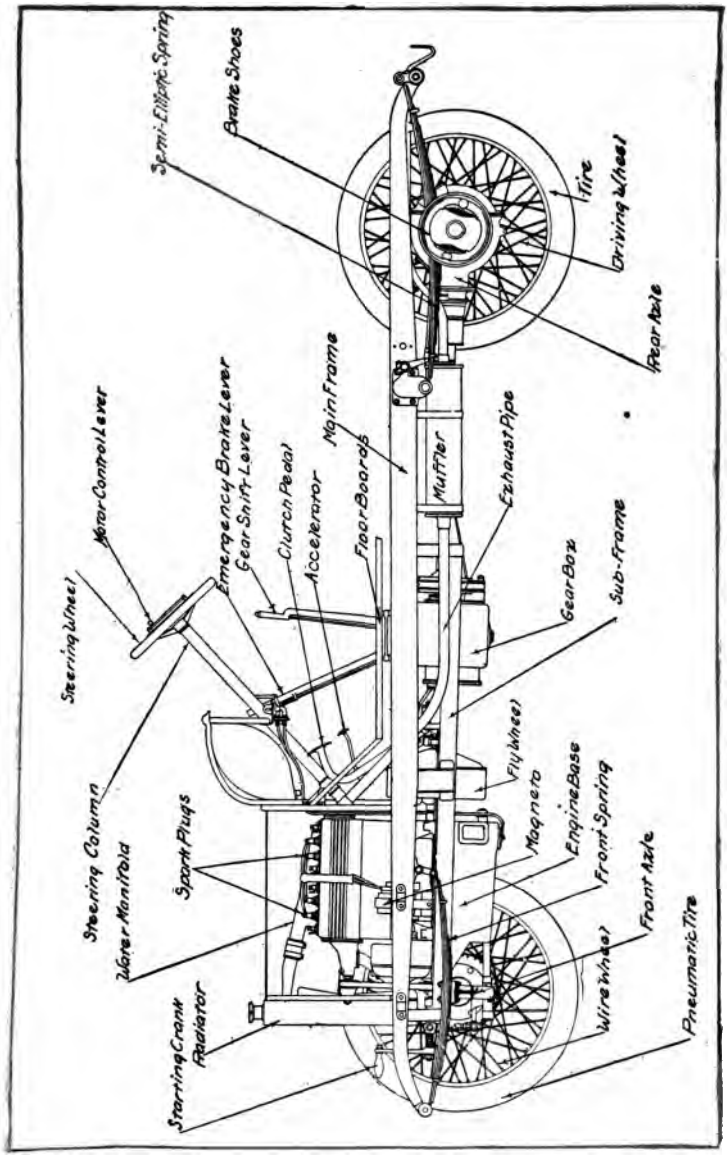


Fig. 5.—Side Elevation Showing Location of Important Components on Typical Pleasure Car Chassis.

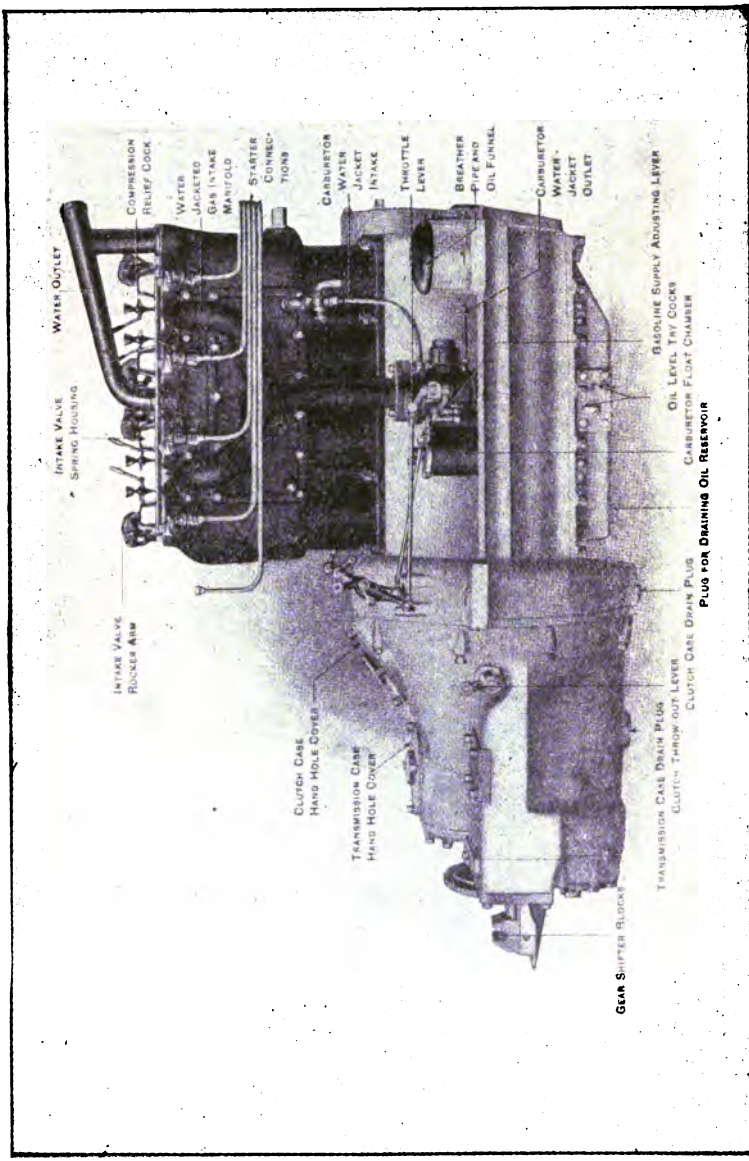


Fig. 6.—Carburetor Side of Chalmers Unit Power Plant.

Q. What does the power plant consist of?

A. The usual gasoline automobile power plant consists of a gasoline engine, a carburetion or fuel supply group, an electrical ignition system, a lubrication system, and means for cooling the engine. (Figs. 6 and 7.)

Q. Name functions of carburetion group.

A. The purpose of the carburetion group is to supply the motor cylinders with an explosive gas.

Q. Name parts of carburetion group.

A. The principal parts of a carburetion group are: a suitable tank or container for the liquid fuel; piping by which this is transfered from the tank to the carburetor or vaporizer which changes the liquid fuel to a gas, and a suitable manifold by which the gas from the carburetor is supplied to the motor cylinder.

Q. Name functions of ignition system.

A. The purpose of the ignition system is to ignite the gas or vapor supplied to the engine cylinder by the carburetion group and to produce power by exploding this gas in the cylinder.

Q. Name parts of ignition system.

A. The parts of the usual electrical system are: some source of electrical current; wires for conveying it from the current producer to a switch or timer which regulates the time the electric spark occurs in the engine; an induction coil or similar apparatus for transforming current of low potential or voltage to current of higher power capable of producing a spark in the cylinder and some form of spark plug which is placed in the combustion chamber and between the points of which the spark that explodes the gas occurs. Some ignition systems consist merely of a magneto or mechanical generator which incorporates in its construction the necessary timing and current intensifying appliances and wires leading from this device to the spark plugs in the motor cylinder.

Q. Why is a lubrication system needed?

A. If the parts of the power plant were not properly oiled, they would wear out very quickly, and in fact it would not be possible to run a gasoline engine for any length of time without supplying oil to

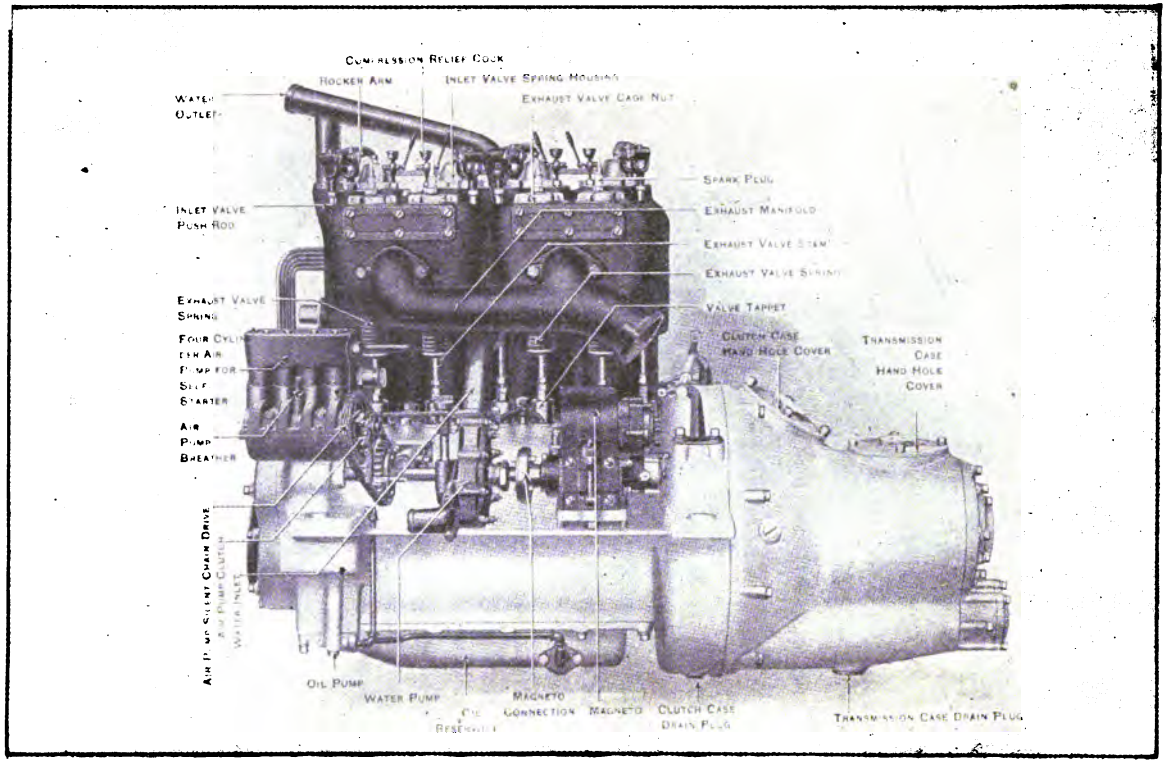


Fig. 7.—Exhaust Side of Chalmers Unit Power Plant.

reduce friction between the piston and cylinder and the other bearings.

Q. What does a lubrication system consist of?

A. A lubrication system, such as commonly used in connection with the gasoline engine, consists of a container or tank in which oil is stored, some form of pump to supply the oil to the bearing points, and piping to convey the oil from the container to the pump, and from the pump to the motor.

Q. What does the cooling system do?

A. As the power of a gasoline engine depends upon exploding gas in its cylinders, it would soon get very hot, due to the high temperature produced by the rapid burning or combustion of gas, and unless it was cooled in some manner and the surplus heat extracted from the metal of which the cylinders are composed, the high temperature existing would soon produce deformation of parts and would put the engine out of commission.

Q. How many types of cooling systems are used?

A. Automobile power plants are cooled by two methods, the simplest of which is to direct a stream of air from a fan or blower on the cylinders, which are provided with flanges to increase the radiating surface, or by passing water thru jackets surrounding the cylinders and afterward cooling this water by passing it thru a radiator exposed to the action of a cooling current of air. Engines are thus cooled either by air directly applied to the heated metal or indirectly utilized when it cools the water which has absorbed the surplus heat of the engine.

Q. What is the purpose of the clutch?

A. The clutch is a simple form of easily operated coupling which makes it possible to run the engine independently of the rear wheels when desired.

Q. Why is change speed gearing needed?

A. Change speed gearing is necessary to provide easily changed ratios of drive between the engine crank shaft and the rear wheels to suit varying road conditions. The gears that give reverse motion to the car are also usually included in the change speed gear set.

Q. How is power usually transmitted to the wheels?

A. The common method of transmitting power from the gear set to the wheels is by means of a shaft and universal joints to a pair of bevel gears or a set of worm gears at the rear axle or by sprockets and chain.

Q. What are the features of chain drive?

A. Power transmission by chains make it possible to obtain varying ratios of drive very easily by merely altering the sizes of the sprockets, and provides for power transmission with minimum loss if the drive is solely by chain.

Q. What are the advantages of enclosed gear drive?

A. Enclosed gearing may be kept free from dirt and grit, and as protected gears may be operated continually in a bath of lubricant, they are not only quiet in operation, but are very enduring and efficient.

Q. Why is the frame needed?

A. The frame is one of the most important parts of an automobile inasmuch as it supports the power plant and power transmission mechanism, forms a connecting link between the axles and the machinery, carries practically all of the controlling elements and power p ant auxiliaries, and serves as supporting member for the body which carries the load or passengers.

Q. How is the frame supported?

A. The frame is supported by and attached to the axles thru the medium of resilient members called springs.

Q. How do the front and rear axles differ?

A. The front axle is simpler than the rear and is used only for steering. The wheels are mounted on steering knuckles which are attached to the ends of the axle and which may be moved to the angle necessary to allow the wheels to follow a curve when going around a corner. The rear wheels are attached to the axles in such a way that they cannot move relative to the axle, except to turn around with them, and the general construction of the rear axle on most cars includes the differential and drive gearing.

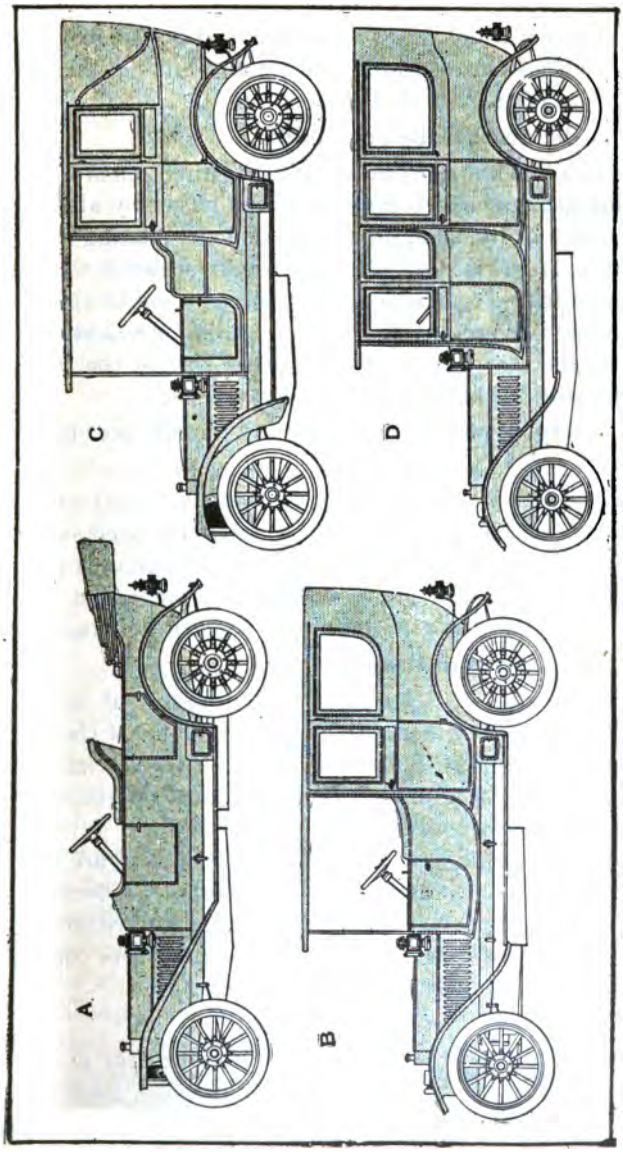


Fig. 8.—Touring Body Types Usually Fitted on Pleasure Car Chassis. A—Open Five-Passenger Torpedo Body. B—Limousine Body. C—Landaulet. D—Berline.

Q. How is the automobile steered?

A. A hand wheel which is placed convenient to the driver actuates the front wheels thru suitable gearing and links and is used to alter the position of the wheels for steering.

Q. How is the automobile controlled?

A. An automobile is controlled as far as its direction is concerned by the steering gear; its speed may be varied either by altering the speed of the motor or by changing the ratio of the gearing by means of a gear shift lever. It is started by means of the clutch which connects the engine to the rear wheels thru the medium of the change speed gearing, and it is stopped by suitable brakes or retarding members applied to the rear wheels or some other part of the transmission system by suitable hand or foot operated lever

Q. How many types of automobile wheels are generally used?

A. The wheels of an automobile may be of the usual wood construction so widely used on horse drawn vehicles changed somewhat in detail, or they may be of the wire spoke form similar in principle to those used on bicycles. In both cases it is obvious that the construction is changed so that the required strength is obtained.

Q. How many forms of tires are used?

A. Automobile tires are usually composed largely of rubber and fabric, and may be of the pneumatic or inflated type, of the cushion form, or of solid rubber. Some very heavy commercial vehicles have used wood block tires, others have used steel or iron tires just as utilized on horse drawn vehicles.

The non-resilient forms, such as wood blocks or steel, are not suitable except on very heavy, extremely low speed trucks, because they are not easy riding enough to support the mechanism without undue vibration, which causes rapid depreciation of the parts comprising the power plant and power transmission members.

Q. What are the principal body types?

A The principal body types fitted to pleasure car chasses are shown at Fig. 8. These are the touring, limousine, landaulet and berline. A roadster body is outlined at Fig. 9, while the coupe form, which is usually employed to replace a roadster body when a closed

car is desi ed, having a capacity for but two or three passengers, is shown at Fig. 10. Truck bodies vary very widely according to the nature of the work they are intended for. The simplest form is a platform without sides, then stakes may be added to this platform body or various forms of closed wire panel delivery bodies or express wagon types fitted to the chassis.

Q. What are automobile bodies made of?

A. P easure car bodies may be made of wood or metal. Sometimes the panels are o sheet steel or aluminum attached to a wooden frame, or the body may be made entirely of metal. Motor truck bodies are usually made of wood and well ironed and strengthened by braces and angle pieces of steel or iron. The floors of motor trucks are often reinforced with strips of bar steel and the corners are provided with corner pieces of metal where they are liable to come in contact with a loading platform.

Q. What are "torpedo and stream line" bodies?

A. It is now common practice to make bodies of pleasure cars designed for high speed of such form that air resistance is reduced to a minimum. This is accomplished by the use of gradual curves and unbroken sides. The name torpedo has been applied to this form of body because in the exaggerated forms they resemble a projectile of this nature on wheels.

Q. Under what conditions is air resistance noticed?

A. Air resistance is of little moment on car speeds lower than 30 miles per hour, but as this rate is exceeded, it is a very important factor which must be recognized, and the amount of exposed area of the car which will offer resistance should be reduced to as low a point as possible. The amount of power needed to overcome air res stance varies inversely as the cube of the speed. This means that if the speed of the car is doubled the power needed to overcome air resistance at half that speed is multiplied by eight. For instance, if one horsepower is absorbed at 20 miles per hour, 8 horsepower will be required to overcome the air resistance present at 40 miles per hour. It is for this reason that the torpedo body has been evolved and in most modern cars the frontal area, which means the number

of square feet in the radiator, dash, wind shield, mudguards, and other parts that would offer resistance to motion, is kept as low as possible.

Q. What is traction resistance?

A. It takes a certain amount of power to overcome the friction existing between the wheels and the ground due to the car weight, and to produce movement of the vehicle. This is known as traction resistance and depends largely upon the nature of the road surfaces, the size of the driving wheels and the type of tire with which they are fitted.

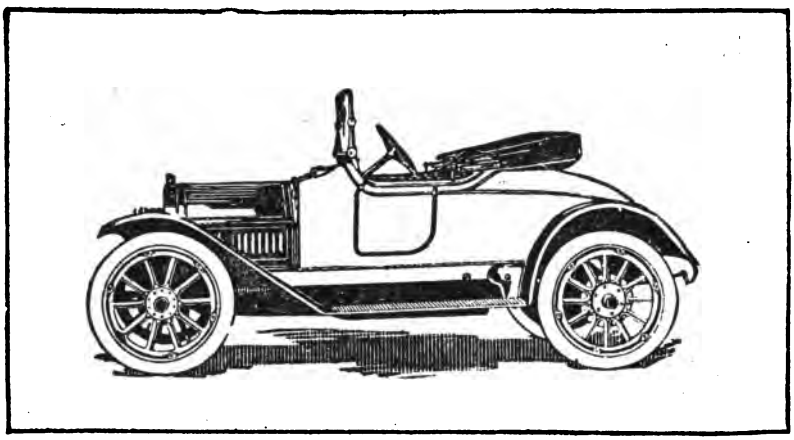


Fig. 9.—Typical Two-Passenger Roadster Body on Pleasure Car Chassis.

Q. What is the resistance of grades?

A. When an automobile is climbing a hill, it must lift its weight in opposition to the force of gravity, which exerts no retarding influence when the automobile is operated on the level, and which really accelerates car motion when the automobile is descending an incline. It requires an effective effort or push at the point of contact between the rear wheels and the ground equal to one per cent of the car weight for each one per cent increase in gradient.

Q. How much power does an automobile need?

A. The amount of power required to propel an automobile de-

pends upon the nature of service for which it is intended. A high speed car of comparatively light weight may require more power than a heavily loaded, slow moving truck. An automobile that is to be used in hilly country or where road conditions are not good, needs more power than a machine of the same type operated under more favorable conditions. This is a point that is hard to decide, and no general rules can be given. If an automobile has too much power, it will use an excess of fuel over the amount actually needed to propel the vehicle and will rack itself to pieces sooner than one that is lacking in power. The under-powered car, however, usually performs very well on the level and under favorable conditions, but it is very unsatisfactory when used on hills or bad roads. Much depends upon the general design of the automobile, and the efficiency of the power transmission and driving elements.

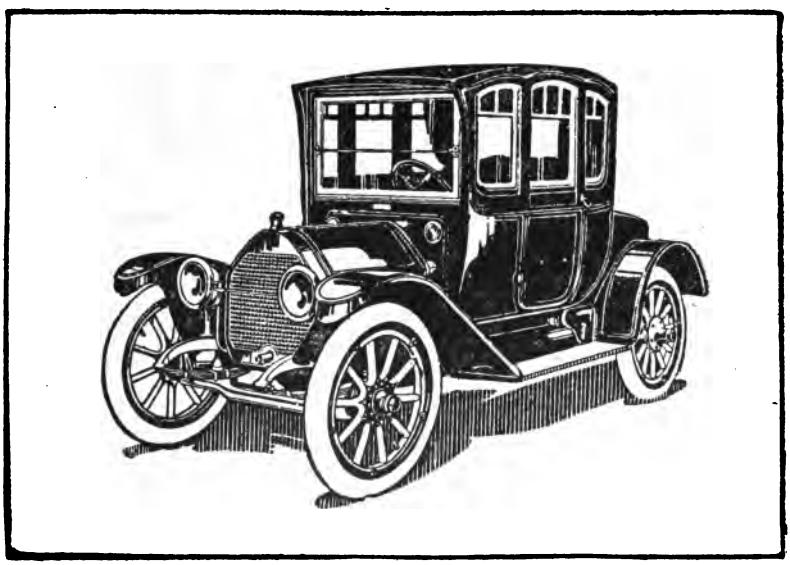


Fig. 10.—Coupe Body, a Closed Type Suitable for Two or Three Passengers Fitted to Roadster Chassis.

Q. What is the usual proportion of power to weight?

A. Pleasure cars that are intended for touring or high speed

work, usually have one horsepower for each 50 pounds car weight. Medium speed touring cars and runabouts usually have one horsepower for each 75 pounds car weight. Delivery wagons designed for speedy service usually employ a power plant of such size that one horsepower is provided for each 100 pounds, while designers of heavy motor trucks that operate at very low speeds find that one horsepower to two or three hundred pounds weight is adequate.

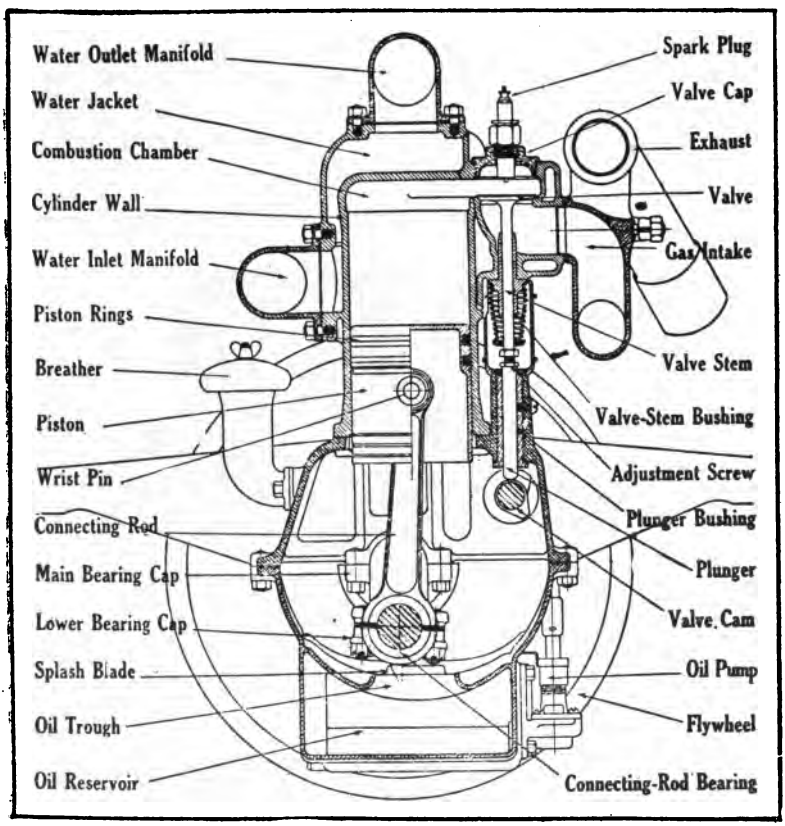


Fig. 11.—Sectional View of Overland Engine Showing Important Parts.

LESSON TWO

ACTION OF THE TWO AND FOUR-STROKE CYCLE MOTORS

Q. Describe the operating principle of the gas engine.

A. Power is obtained in a gas engine by exploding some combustible vapor or gas in a closed cylinder which is provided with an internal yielding member moved by the force of the explosion. The moving member converts the expansive power of the rapidly burning gases to mechanical energy by suitable leverage. The gas engine is a form of heat engine just as the steam or hot air motor.

Q. How does the gas engine differ from the steam engine?

A. The gas engine, while it embodies some of the main elements used in a steam engine, differs greatly in general design. The cylinder is provided with a water jacket and most of the gas engines used as automobile power plants have the connecting rod attached directly to the reciprocating member or piston in the cylinder instead of to a crosshead as used in a steam engine Most forms of steam engines are double acting. That is to say, the steam is admitted first to one end of the cylinder, and then to the other, and both ends of the piston take a power impulse. All gas engines used in automobiles or similar vehicles are single acting, which means that the expansion of gas that produces the power takes place in the upper end of the cylinder and against the top of the piston only.

The power of a steam engine can be increased within certain limits by augmenting the pressure and quantity of steam supplied the cylinder. The effective force obtained by the explosion of gas in a gasoline engine attains a certain maximum volume which cannot be increased. It is possible to start a steam engine under load,

while a gasoline engine can be started under these conditions only by means of some mechanical starting arrangement that will enable the crank shaft to be turned until a charge of gas has exploded in the cylinder. A steam engine starts as soon as steam is admitted to the cylinders. A gas engine as used in automobiles will not start unless the crank shaft is rotated by a starting handle or some other mechanical equivalent. A steam engine is an external combustion motor while the gas engine is an internal combustion type.

Q. Define "external" and "internal" combustion.

A. External combustion means burning the fuel which produces power outside of the cylinder as is the case when water is heated in a steam boiler, which is separate from the steam engine. Internal combustion is what takes place when the gas that produces the heat from which power is obtained is burnt or exploded directly against the piston in the cylinder. An engine which depends upon the internal combustion principle is more efficient than an external combustion form because loss of heat is less.

Q. How is fuel supplied to gas engine cylinders?

A. The gas, which may be derived from the burning of coal in a gas producer, manufactured by the usual methods of making illuminating gas or taken from natural underground sources as natural gas, is supplied to the cy inders of a gas engine directly from the source of supply through the medium of piping which leads to the combustion chamber of the motor. When liquid fuel such as gasoline or kerosene is used, it is first transformed into a gas by atomizing or spraying a small quantity of the liquid into an entering charge of pure air which changes the liquid spray to a vapor that afterward mixes intimately with the air to form an inflammable gas.

Q. What is necessary before the gas in the cylinder can be exploded?

A. Before exploding the gas charge it is customary to compress it into from one-third to one-fifth of the cylinder volume. A charge of gas that is not compressed will burn comparatively slow and will not produce much power. The more the gas charge is compressed the greater the force of the explosions. There is a limit to the amount of compression, because if kerosene or gasoline vapor pressure is in-

creased over 120 lb. per square inch, it will be exploded by the heat derived from compressing the charge.

Q. What is the difference between "explosion" and "combustion"?

A. The difference is merely a matter of time, as an explosion is rapid or practically instantaneous combustion.

Q. Why does expansion of gas produce power?

A. When the gas charge which has been compressed to a point ranging from 60 to 90 lb. per square inch before ignition is exploded its tendency is to expand and regain the volume it occupied before compression. As the increase in temperature due to burning produces an actual increase in volume, considerable pressure is directed against the sides of the container in which the gas was exploded. If one of these walls is a yielding member it will be forced outward by the pressure of the gas which ranges from 300 to 400 lb. per square inch if the charge has been fired normally, and even higher than this if the charge has preignited, or exploded before the proper time.

Q. What are the main elements of any gas engine?

A. The main elements of a gas engine are a containing chamber in which the gas is exploded, which is called the "cylinder," and a yielding member termed the "piston" against which the force of the explosion is directed. The piston is joined to a crank shaft by means of a movable link called the connecting rod which transforms the reciprocating or back and forth motion of the piston to a rotary or turning movement of the crankshaft. (Fig. 11)

Q. What is the two-stroke cycle principle?

A. In the two-stroke cycle engine the piston makes but two strokes and the crankshaft one revolution for each explosion in a single cylinder motor. On the upward stroke of the piston a gas charge which has been previously transferred to the interior of the cylinder is compressed by the upward movement of the piston and at the same time a charge of fresh gas is drawn into the engine base, due to the suction of the piston as it moves upward in the cylinder. When the piston reaches the top of this stroke the gas above it is compressed ready for ignition while the cylinder and crankcase be-

low it are also filled with gas. The electric spark takes place just as the piston reaches the top of its upward movement and explodes the gas under compression in the combustion chamber. This explosion drives the piston down and at the same time it compresses the charge of gas in the engine base.

Just a little before the piston reaches the bottom of its stroke a port in the cylinder wall is uncovered by the piston and the burnt gases escape. When the greater part of the heat of the exhaust gas

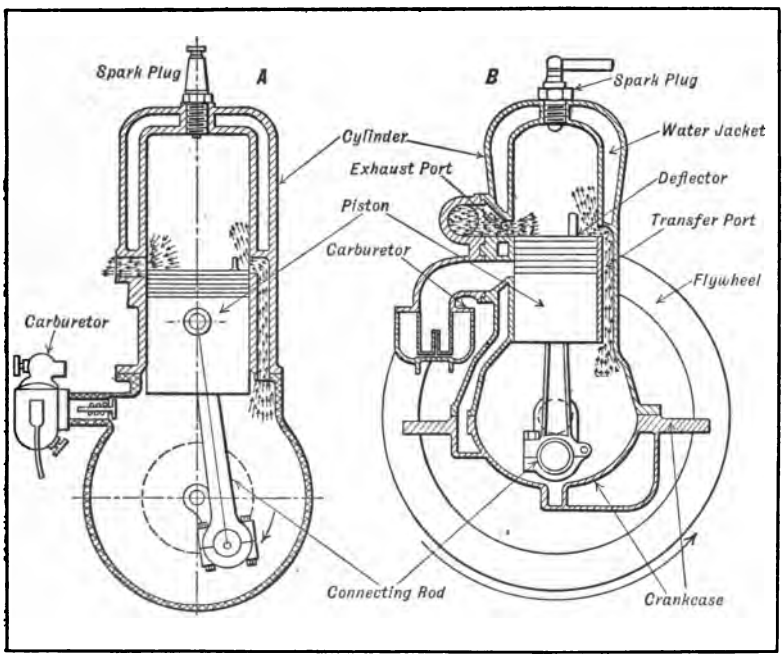


Fig. 12.—Two and Three Port Two-Cycle Engines Compared. A—Typical Two-Port Design With Automatic Valve in Crank Case. B—Conventional Three-Port Design With Charging Port Controlled by Piston Movement.

has been disposed of the piston uncovers another port on the opposite side of the cylinder which communicates with the engine base interior and the charge of fresh gas which is under compression at that point is transferred through a bypass or transfer passage from the lower part of the piston to the portion of the cylinder above the

piston top. This entering stream of fresh gas strikes a deflector plate interposed between the inlet and exhaust port across the top of the piston so the fresh charge of gas is directed to the upper portion of the cylinder instead of passing out through the now fully opened exhaust port. The piston is moved up to the top of the cylinder again by means of momentum or energy stored in the engine flywheel and operations of compressing the gas above the piston top and charging the lower portion of the engine base with gas are again effected. When the piston reaches the top of the cylinder the gas is again exploded and this cycle of operations continues as long as fuel is supplied the cylinder and a spark is provided to ignite it at the proper time. (See Fig. 12.)

Q. What is the four-stroke cycle principle?

A. The four-stroke cycle engine, commonly termed the "Four cycle" or Otto cycle, differs from that previously described in that four strokes of the piston are necessary to obtain an explosion in the cylinder. The operation of this form of engine is clearly outlined at Fig. 13. The first stroke of the piston which is shown at *A* is a down stroke or movement from the closed to the open end of the cylinder. During this suction or intake stroke a vacuum or suction is produced in the cylinder and an inlet valve member opens to admit a charge of gas which is drawn in by the pumping action of the moving piston. This inlet valve remains open during the entire first down stroke, and closes when the piston reaches the end of its downward movement.

The second stroke of the piston is depicted at *B*. This is an upstroke in which the piston moves from the open to the closed end of the cylinder. The intake valve, which has been open on the first stroke, is closed, as is also the exhaust valve which is utilized to close the passage through which the burnt gases are expelled. During this upward movement the charge of gas which has been previously drawn into the cylinder is compressed. At the end of this stroke, an electric spark takes place to explode the gas.

The third stroke which is outlined at *C* is termed the "explosion or power stroke." In this the piston is driven down by the expanding gas with a force depending upon the area of the piston top and its position in the cylinder. At the instant of combustion a pis-

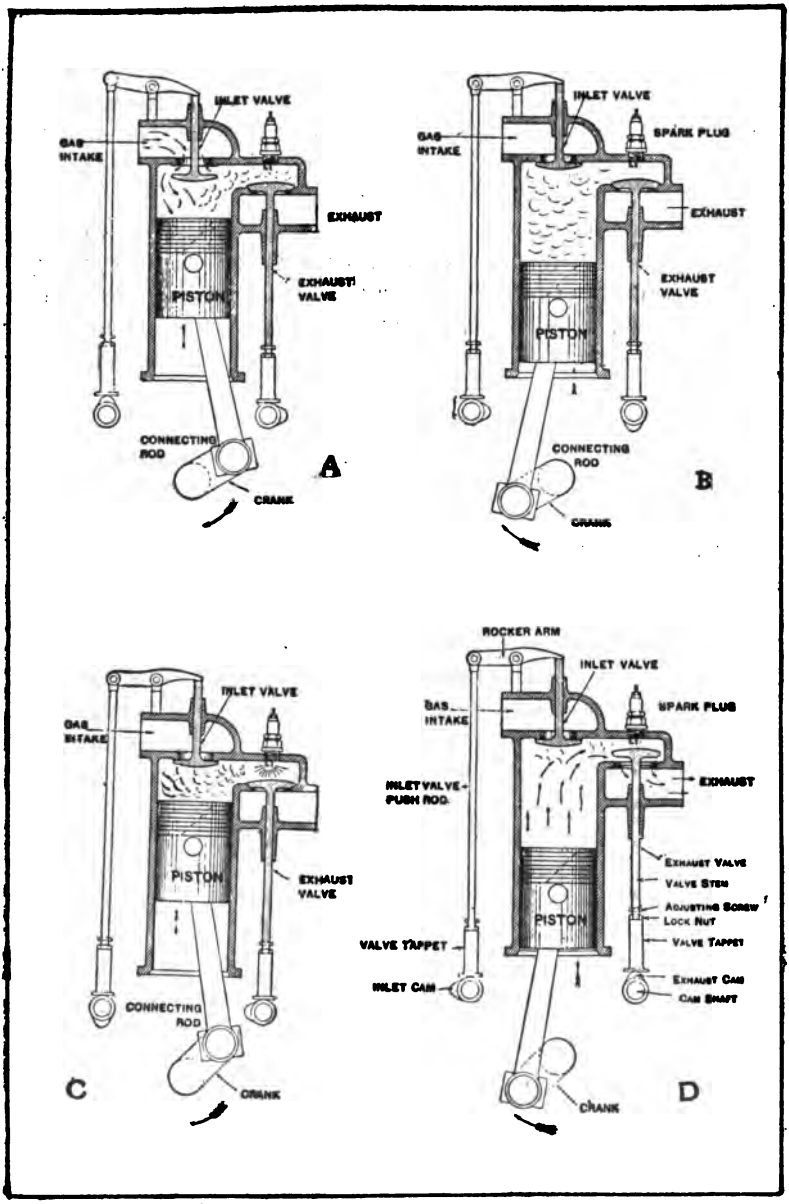


Fig. 13.—Diagrams Illustrating Four-Cycle Motor Action.

ton with an area of 100 square inches will receive an impulse varying in value from 10 to 15 tons. As the piston goes further down on its stroke, and the burnt gases expand more, the pressure becomes reduced to a point where the gases have so little pressure that it is better to dispose of them than to take further advantage of their expansive force.

The power of a gas or gasoline engine is usually figured on a basis of mean effective pressure of 80 to 100 lb. per square inch, which is considered as existing during the entire stroke of the piston. When the piston reaches approximately seven-eighths of its stroke following the explosion, the exhaust valve is raised by a cam member and the inert gases escape through the open exhaust port by virtue of their pressure. The next stroke of the piston is outlined at *D* and is termed the "exhaust" or scavenging stroke, and it is devoted exclusively to clear the cylinder of the burnt gases. These are pushed out by the upward movement of the piston, and when the piston reaches the end of its stroke the exhaust valve closes and the inlet valve opens again to admit a fresh charge of gas during the suction stroke.

It will be seen that in a four-cycle engine the piston must make twice as many strokes as in a two-cycle. This is because all the work is done in the upper portion of the cylinder and by the piston top. One entire piston stroke is necessary to fill the cylinder, and a full piston stroke is devoted to clearing the cylinder of burnt gas. In a two-cycle engine, these two operations are performed at practically the same time.

Q. Name advantages of two-cycle engine.

A. Owing to the more rapidly occurring series of explosions, a two-cycle engine has a much more even torque, which is synonymous to more uniform power application. A two-cycle engine is much simpler than four-cycle, as in its simplest form it comprises practically only the essential elements absolutely necessary to secure power from the explosion of gas. There are but three moving parts, namely, the piston, connecting rod and crankshaft. As the ports through which the gas enters and leaves the cylinders are opened and closed by the piston the use of valves which are necessary with a four-cycle engine is dispensed with.

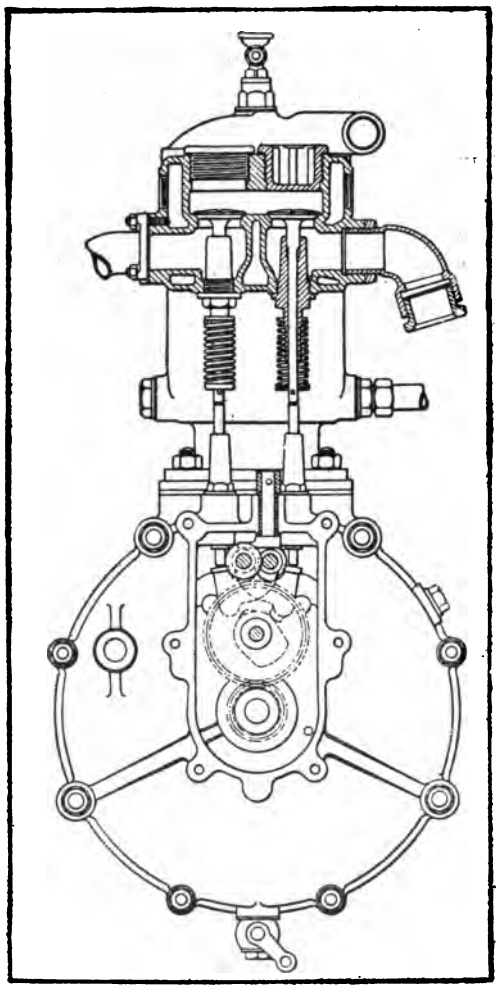


Fig. 14.—Sectional View of Valve Chest of the De Dion Form of Single Cylinder Motor.

Q. How many types of two-cycle engines are used?

A. Three main types of two-cycle engines are generally used. These are the two-port, three-port and differential piston forms.

Q. What is a two-port, two-cycle engine?

A. A two-port two-cycle engine is shown at Fig. 12 A. In this form of motor the gas enters into the crankcase, through a passageway in that member, which is closed by an automatic valve of the mushroom type. It is called a two-port engine because but two ports are provided in the cylinder walls. One is for disposition of the exhaust and the other permits the fresh gas to enter the cylinder. Both of these ports are uncovered or fully open when the piston reaches the bottom of its stroke, or when approximately in the position shown.

Q. What is the three-port, two-cycle engine?

A. The three-port, two-cycle engine is so called because there are three ports in the cylinder wall instead of two. One of these ports

serves as a means for gas entrance to the engine crankcase and is fully opened only when the piston reaches the top of the cylinder or the end of the up-stroke. The other two ports are exactly the same in location and perform the same functions as do those in the two-port engine. The three-port is the simplest form and is a truly valveless motor, inasmuch as the two-port engine utilizes an automatic inlet or check valve to prevent the gas from escaping from the crankcase interior when the piston is moving down. In a three-port engine the piston wall itself covers the intake or charging port to which the carburetor is attached as it descends on its power stroke and no check valve is necessary in the engine base.

Q. What is a "differential" piston, two-cycle engine?

A. This form of motor utilizes a piston which has an enlarged lower portion so that it is virtually a double member. The lower portion of the cylinder bore is enlarged to fit the larger diameter of the piston and a pumping chamber is thus formed. The inlet gas is drawn into this chamber and compressed therein prior to transfer into the upper or working end of the cylinder instead of into the engine base.

It is claimed that it is easier to keep a pumping chamber of cylindrical form tight than it is to have an absolutely tight engine base. As the bearings of the ordinary form of two-cycle engine wear, a certain amount of air is drawn in through the worn bearings and dilutes the mixture in the crankcase and at the same time the amount of compression which insures prompt transfer of the gas charge from the engine base to the cylinder is reduced because of this leakage. In a differential piston engine, piston rings are depended on to keep the lower piston tight in its pumping cylinder and the engine operation is not affected by bearing depreciation.

Q. What are the disadvantages of two-cycle motors?

A. Two-cycle motors are not as efficient as the four-cycle forms, because it is practically impossible to expel the burnt gases and fill the cylinder with fresh gas at the same time without serious mixing. The dilution of the fresh gas by the inert burnt products reduces its power and it will not explode as readily as pure, fresh gas will. Then

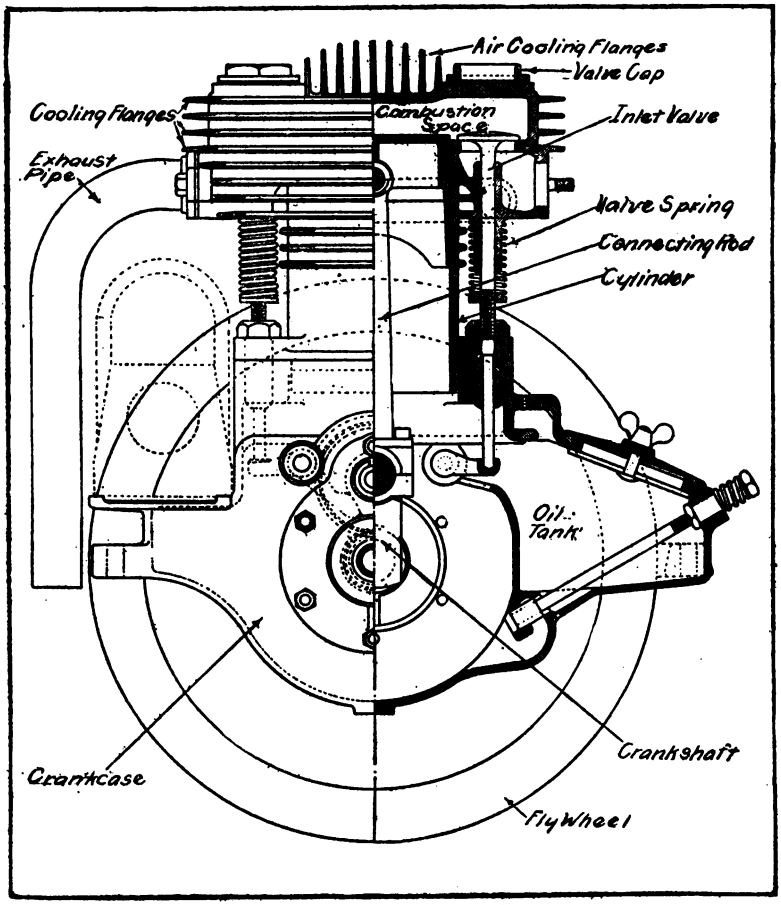


Fig. 15.—Part Sectional View of Single Cylinder T Head Air-Cooled Tri-Car Motor of English Design.

again, a certain amount of the fresh charge invariably flows out of the open exhaust port before this is closed by the upwardly moving piston. The two-cycle engine will not throttle down as well as a four-cycle, nor will it attain as high speeds. Two-cycle engines are rather sensitive to mixture variations, and instead of developing twice the power that a four-cycle of the same piston displacement or cylinder dimensions will give, they only deliver about 1.5 times the

power and use twice as much fuel. Two-cycle engines are not as flexible as the four-cycle form and do not respond as readily to throttle control. They are not as satisfactory for general automobile service as four-cycle engines are, and have not received very wide application as automobile power plants.

Q. Where are two-cycle engines widely used?

A. Two-cycle engines are entirely suitable for use where a wide range of speed variation is not desired, and have been successfully applied as stationary engines and motor boat power plants.

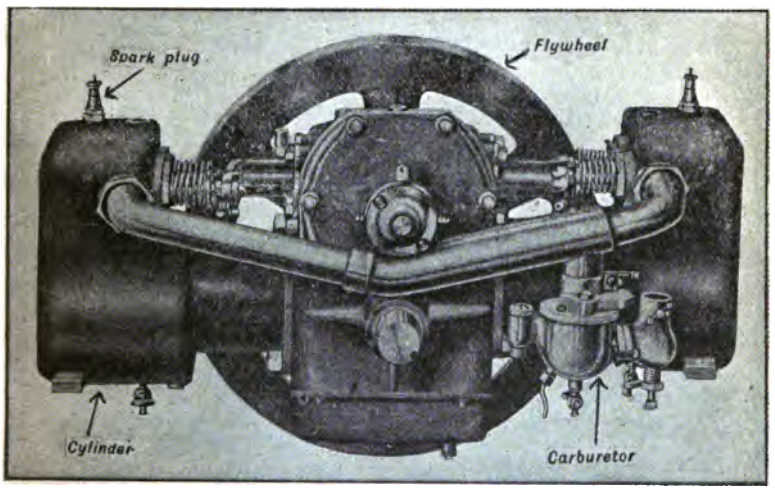


Fig. 16.—Simple Two-Cylinder Opposed Water-Cooled Motor.

Q. What are the advantages and disadvantages of four-cycle engines?

A. When a four-cycle engine is compared to the two-cycle form it is apparent that it is more complicated, inasmuch as it has many small parts that are liable to make trouble which are not found in a two-cycle motor. At the other hand the four-cycle form is the more flexible and economical of fuel, as a full stroke of the piston is devoted to charging the cylinder with gas and the inlet valve closes as soon as the cylinder is filled, so there is no opportunity for the fresh gas to escape or to become diluted with exhaust or dead gas.

An entire stroke of the piston and part of the power stroke is devoted to clearing out the burnt gases so that the cylinder of a four cycle engine is more thoroughly scavenged than is that of a two-cycle motor. A four-cycle engine responds readily to throttle control and its speeds may be accelerated from a few hundred revolutions per minute to several thousand without lack of uniformity or the back-firing usually present when a two-cycle engine is accelerated too quickly. A four-cycle engine will run faster than the two-cycle form and it is also able to run slower when the supply of gas is reduced.

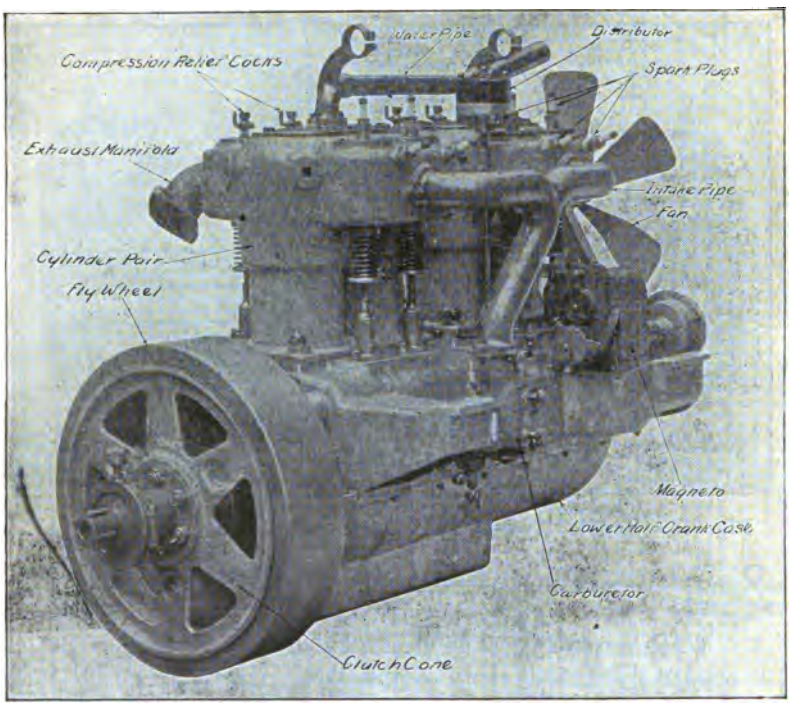


Fig. 17.—Inlet Side of Typical Four-Cylinder Water-Cooled Motor.

Q. How many cylinders do gas engines have?

A. Gas engines used for automobile power plants usually have four or six cylinders. Formerly simple types of one and two cylinder motors were very popular, but at present these have been largely

displaced by the multiple cylinder form. Racing automobiles have been made with eight, twelve, and sixteen cylinders, but eight cylinders have been the greatest number ever used on a stock touring car.

Q. What is the advantage of a one-cylinder engine?

A. The main advantage of a single cylinder motor is that of simplicity. Practically no one-cylinder automobiles are on the market at the present time, though many one-cylinder cars of early vintage are still giving satisfactory service.

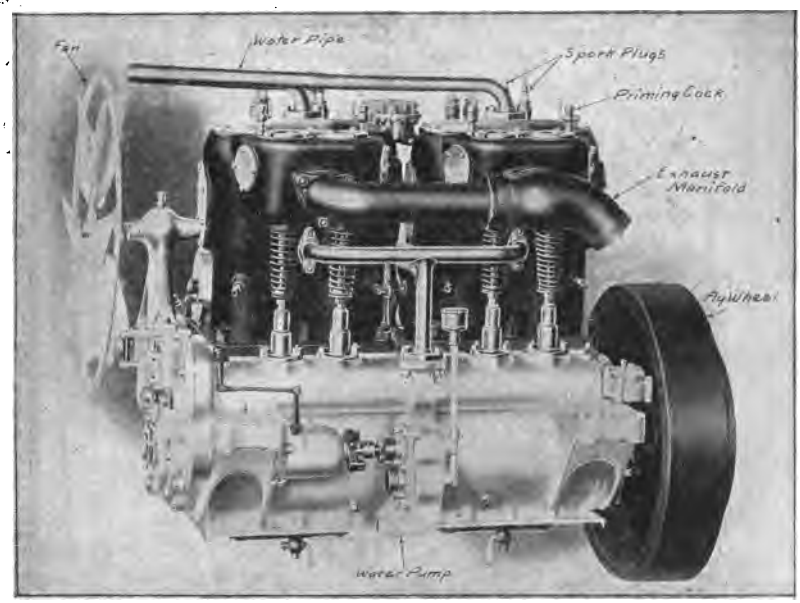


Fig. 18.—Exhaust Side of Four-Cylinder Water-Cooled Motor Used on Peerless Automobiles.

Q. Why are multiple cylinder engines superior to simple types?

A. Multiple cylinder engines are smoother running because they deliver power more uniformly than do the simple one and two cylider engines.

Q. How many explosions per crankshaft revolution are obtained with various forms of four-cycle engine?

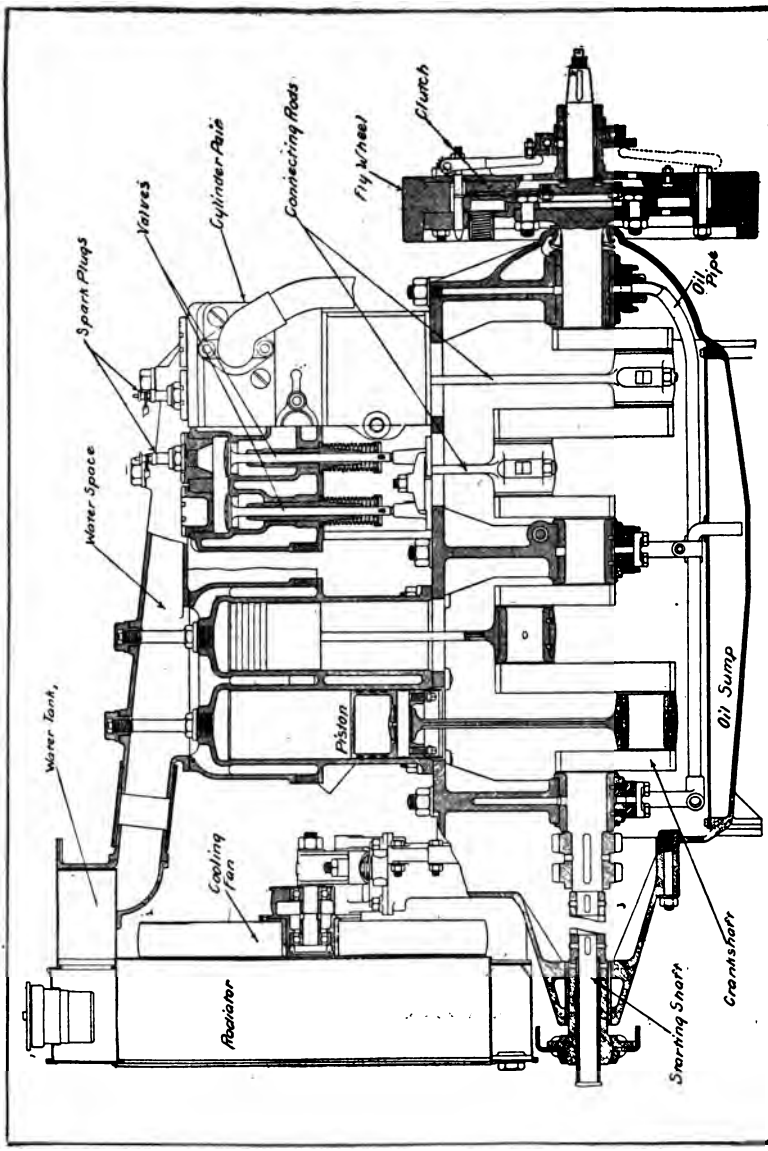
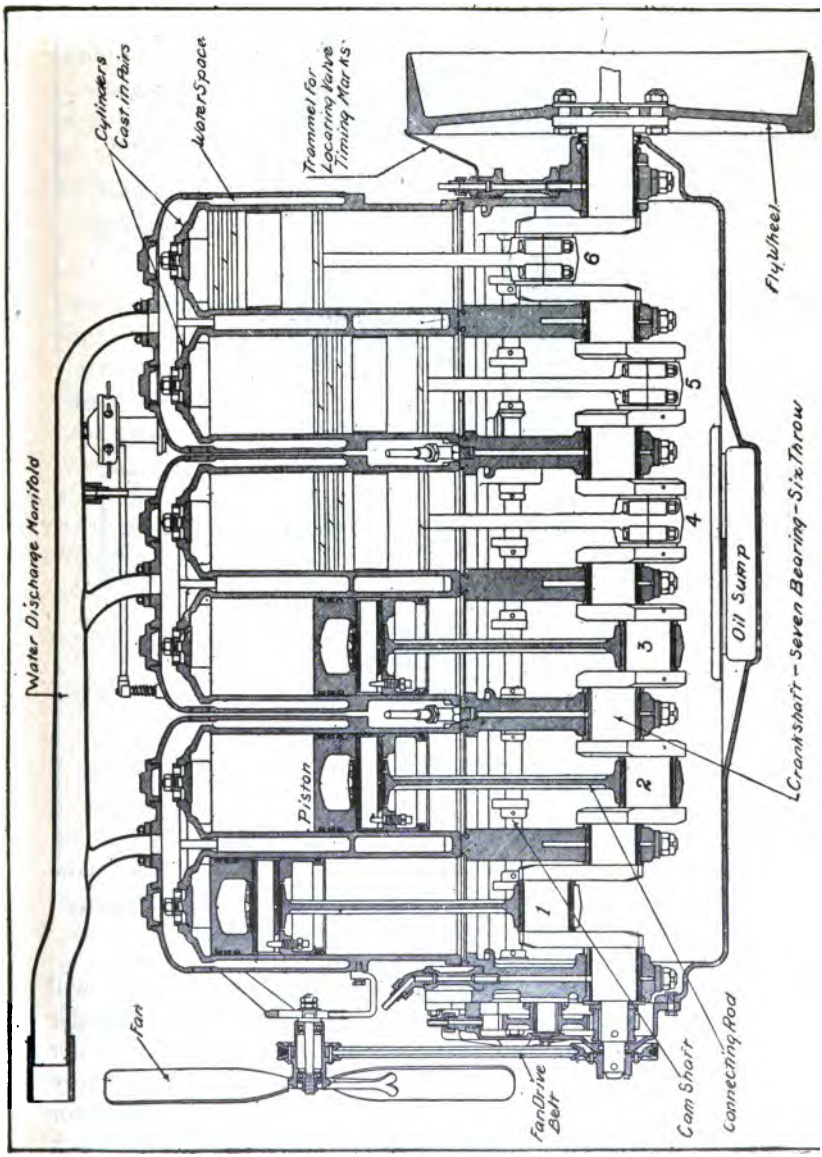


Fig. 19.—Part Sectional View of Four-Cylinder Motor Showing Radiator and Clutch. Note Three Bearing Crankshaft and Cylinders Cast in Pairs, Also Large Water Manifold.


Water Discharge Manifold
Cylinders Cast in Pairs
Water Space
Trammel for Locating Valve Timing Marks
Flywheel
Piston
Fan
Fan Drive Belt
Cam Shaft
Connecting Rod
Crankshaft – Seven Bearing – Six Throw
Oil Sump
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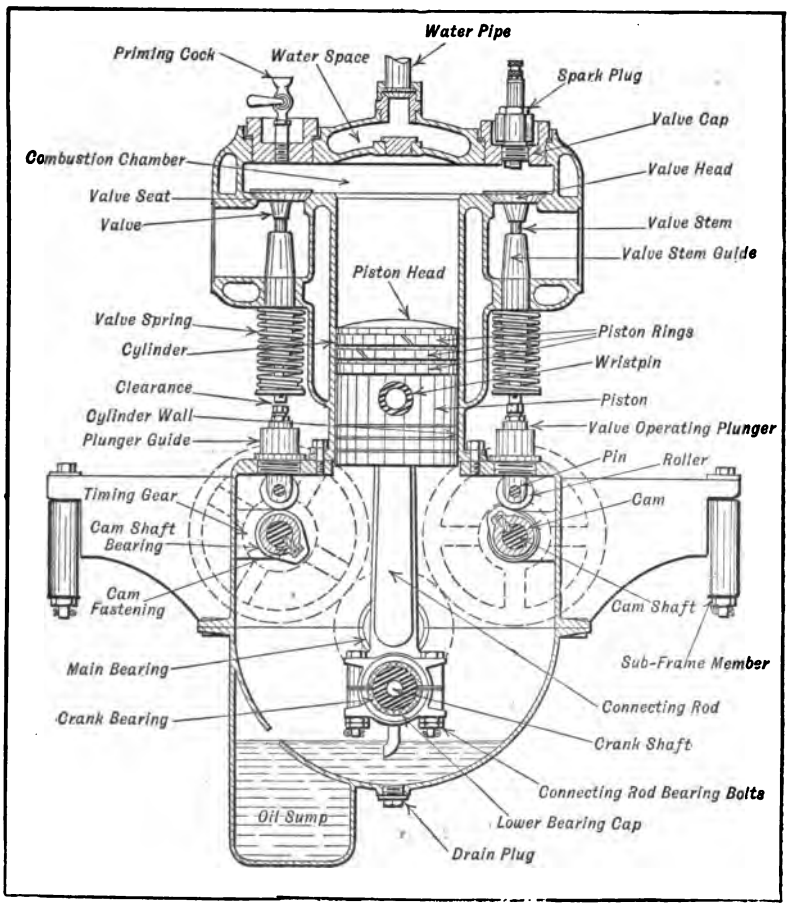


Fig. 21.—End Sectional View of Motor With T Head Cylinder Showing Important Parts.

A. The crankshaft of a single cylinder four-cycle engine will receive one impulse every two revolutions. That of a two cylinder form will receive an impulse every revolution. A three cylinder crankshaft will receive three impulses in two revolutions or one every two thirds crankshaft revolution. Four explosions are obtained for every two revolutions of a four cylinder crankshaft or two each

revolution. Three impulses are given to the crankshaft of a six cylinder engine per revolution and that of an eight cylinder motor receives four impulses per crankshaft revolution. It will be apparent that the greater the number of cylinders the smoother the engine operation will be because the crankshaft receives more power strokes in a unit of time. A two-cycle motor crankshaft will receive twice as many impulses per revolution as that of a four-cycle engine having the same number of cylinders.

Q. Are five or seven cylinder engines practical?

A. Five cylinder engines of the conventional form having five throw crankshafts have been made and have operated satisfactorily though they do not run enough smoother than a four cylinder to warrant their replacing this type of standard engine and at the same time their torque is not equal to that of a six cylinder engine, so they have not been applied to automobile service. Any number of cylinders that will go into 360 evenly can be utilized in conjunction with a crankshaft having the same number of throws as there are cylinders, and these cranks may be arranged so that the explosions will follow each other evenly. A seven cylinder engine cannot be made of the usual form, but has been made with cylinders revolving around a fixed crank for aeroplane use. A five cylinder revolving engine was formerly utilized as a power plant on an automobile sold in limited numbers.

Q. What is the limit of engine weight per horse power?

A. The ordinary automobile power plant will weigh about ten pounds per horse power, but very light gas engines for use as aeroplane power plants have been made in the water cooled form that weighed less than five pounds per horse power complete and in the air cooled revolving cylinder forms that weighed but three pounds per horse power. Automobile power plants have been improved greatly in recent years, as 25 or 30 pounds per horse power was not considered excessive weight when the first gas engines were applied to automobile service.

LESSON THREE

PARTS OF GASOLINE MOTORS AND THEIR FUNCTIONS

Q. What are the parts common to all engines?

A. All internal combustion engines, regardless of type, must have the following parts: Cylinder, piston, connecting rod, crankshaft, and engine base.

Q. What additional parts are used only by four-cycle engines?

A. In addition to parts previously enumerated, four-cycle engines must have inlet and exhaust valves, valve operating push rods, valve springs for closing the valves, cams to open them and gearing of some form to drive the camshaft from the crankshaft. (See Fig. 21.)

Q. What is the cylinder and of what material is it made?

A. The cylinder is the portion of the engine in which the gases are confined prior to ignition and which serves as a guide for the piston member which transmits the power of the explosion to the crankshaft. Cylinders are very accurately machined, the bore being about .005" larger than the piston and the interior walls are made straight and true by boring and grinding. Cylinders are invariably made of cast iron of special mixture because this material withstands the heat better than any other and is easily poured into moulds in a molten condition to form very intricate shapes that would be difficult to produce commercially in any other way.

Q. Where is the combustion chamber?

A. The combustion chamber is at the upper end or closed portion of the cylinder. (Fig 21.)

Q. How are cylinders cast?

A. Cylinders may be cast individually, in pairs, or in blocks of three, four or six.

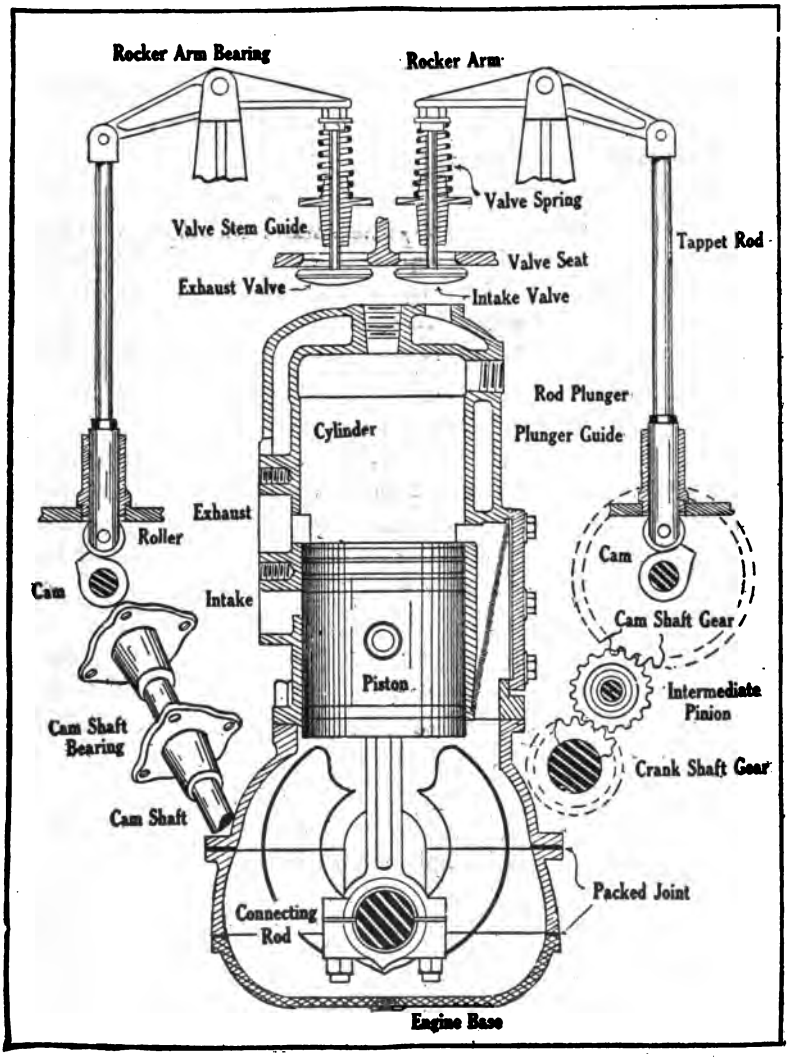


FIG. 22.—Outlining Parts of Two-Cycle Motor and Also Showing the Members Necessary to Secure Action of a Four-Cycle Motor that Are Eliminated in the Two-Cycle Forms.

Q. What is the water jacket?

A. The water jacket is a wall surrounding the cylinder castings and separated from the cylinder wall by a space through which water is circulated around all portions of the cylinder that are liable to become unduly heated while the engine is in operation.

Q. How is it attached to the cylinder?

A. The water jacket is usually incorporated as part of the cylinder by casting it integral. The spaces through which the water circulates are formed by the use of cores made of sand which separrate the two walls until the molten metal which has been poured around and between the cores has had a chance to cool. When the casting is removed from the mould the sand is taken out of the water jackets and leaves a space through which water can circulate.

Q. Are cylinders ever made without jackets?

A. Some forms of water cooled cylinders are cast without the water jacket which is afterward applied, either by an electro-deposition process or by fastening a sheet metal water jacket to suitable flanges on the cylinder by screwing it in place, by brazing or hard soldering it or by any other suitable mechanical means.

Q. What is the valve chamber?

A. The valve chamber is a projecting portion of the cylinder in which the valves are placed that control the gas flow in or out of the combustion chamber and to which the inlet and exhaust manifolds are attached.

Q. Where is it placed on the cylinder?

A. The valve chamber may be placed at one side of the cylinder and of sufficient size for both valves or two valve chambers may be utilized, one placed at each side of the cylinder head and carrying only one valve. When cylinders are cast in pairs and a valve chamber is used on but one side there is room enough for four valves. But when two valve chambers are utilized each need only be large enough to provide accommodation for two valves. Valve chambers are sometimes made in the form of separate castings which are attached to the top of the cylinder or the valves may be housed in cages which are inserted directly into suitable openings made to receive them in the cylinder head. (See Figs. 21, 23, 25, 26.)

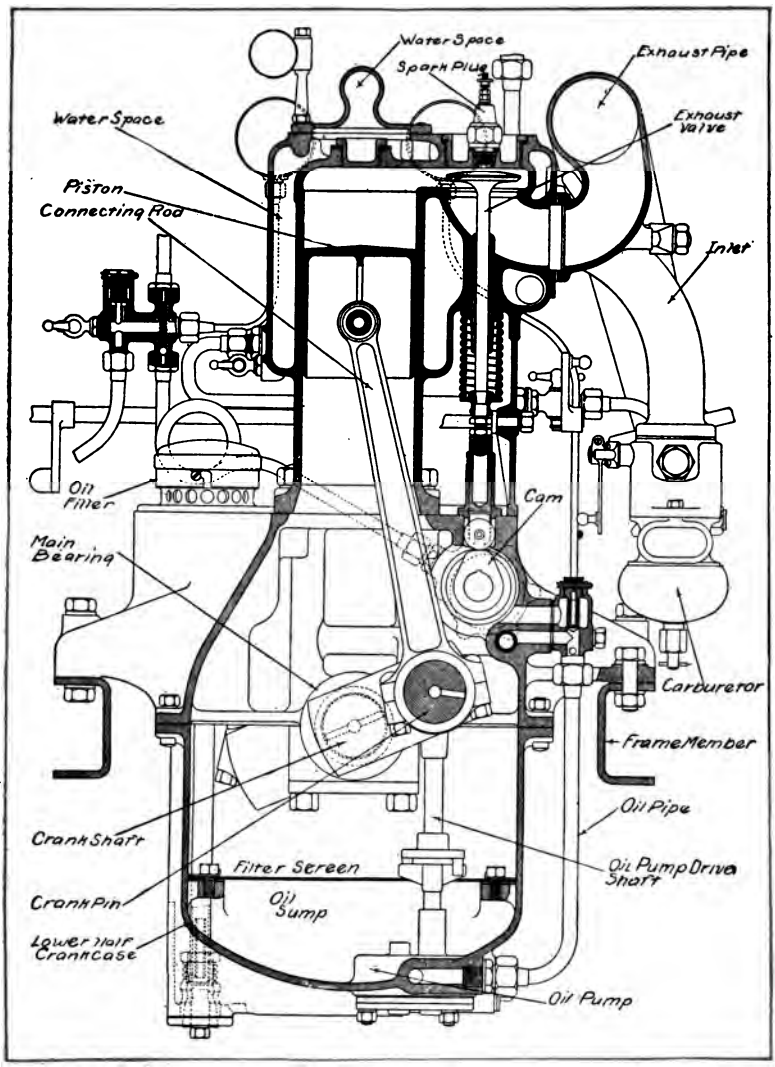


Fig. 23.—End Sectional View of L Head Motor with Important Parts Clearly Outlined.

Q. What is the cylinder head?

A. The cylinder head is the name generally given to the upper or closed end of the cylinder.

Q. Name two methods of constructing cylinder heads.

A. Cylinder heads may be a separate casting attached to the cylinder member by bolts or they may be formed integrally with the cylinder during the casting process. The latter is the conventional method.

Q. What are the advantages of individual cylinders?

A. It is claimed that individual cylinders are simpler to form at the foundry, easier to handle in the machine shop and that they are more cheaply replaced in event of damage than where cylinders are cast in a block. With some form of engines it is possible to use only individual cylinder castings. This is true of the two cylinder opposed form, engines having mechanically applied sheet metal water jackets and air cooled engines. (Fig. 26)

Q. What are the advantages of block castings?

A. Block castings, in which three or more cylinders are cast together, not only make a shorter and more compact cylinder assembly possible, but produce a stronger engine because the cylinder block actually reinforces the engine base. With unit castings of the individual type the engine is longer and the crankcase must be made heavier in order to secure the proper degree of strength. (Fig. 27.)

Q. What are the valves?

A. The valves are members that control the ports through which the gases enter and leave the combustion chamber.

Q. Name two types of valves.

A. Valves are either automatically or mechanically operated and may be of the conventional mushroom or poppet valve type or of the sleeve, slide, piston, ring or rotary disc forms.

Q. Can automatic valves be used for exhaust?

A. Automatic valves cannot be used for exhaust because they can only open when there is a partial vacuum in the cylinder or when the pressure in the cylinder is less than that of the outer air. Auto-

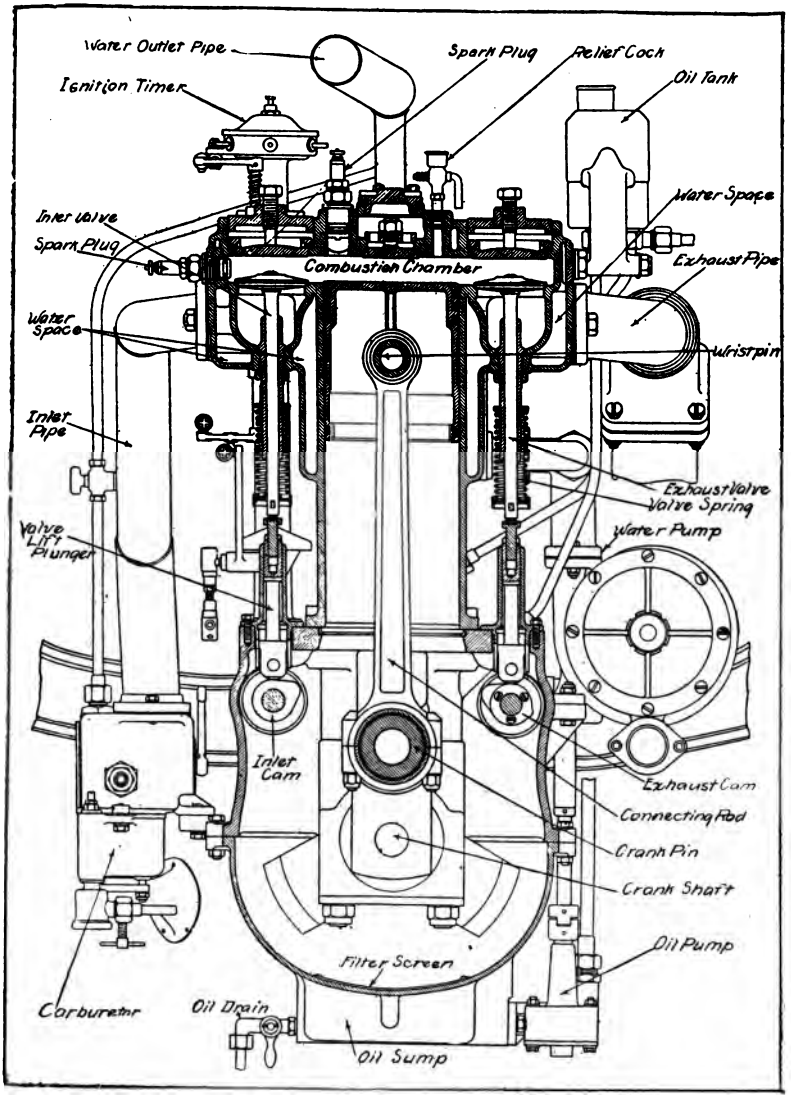


Fig. 24.—Sectional View Through Cylinder and Crankcase of Pierce-Arrow T Head Motor.

matic valves cannot be used except for letting in a charge of fresh gas as they will only open during the suction stroke of the piston.

Q. Why must exhaust valves be mechanically operated?

A. Exhaust valves must be mechanically operated because they are forced to open against the pressure of the burnt gas in the cylinder which may be three or four times that of the atmosphere.

Q. Where are valves placed as a rule?

A. Conventional practice is to place the valves in pockets or valve chambers at one or both sides of the cylinder castings. They are commonly placed so that when opened the entering fresh gas stream will flow directly into the combustion chamber or so the exhaust gas will find a free passage to the outer air.

Q. Describe the three common methods of valve placing.

A. The three common methods of valve placing are at the top of the cylinder opening inward, all valves at one side, or half on one side and the remainder on the other. In some engines one valve may be placed at the top of the cylinder while the other is carried in a side pocket.

Q. How are valves operated?

A. Valves are usually operated by means of push rods which are actuated by revolving cams. The method of valve operation depends upon its placing in the cylinder. If placed in a pocket at the side it may be operated directly by means of a movable p unger interposed between the cam and the valve stems. If placed in the cylinder head it is usually actuated by a push rod and centrally fulcrumed lever which changes the upward movement of the valve plunger to a downward movement of the valve stem. (See Fig. 29.)

Q. What is the advantage of L head construction?

A. It is claimed that greater compactness is obtained by placing all valves on one side of the engine and that the piping is more easily installed. (Figs. 23 and 27.)

Q. What is the advantage of T head construction?

A. Carrying the valves on both sides of the cylinder makes it possible to use larger valve members and ports of greater area for the passage of the gases. (Fig. 24.)

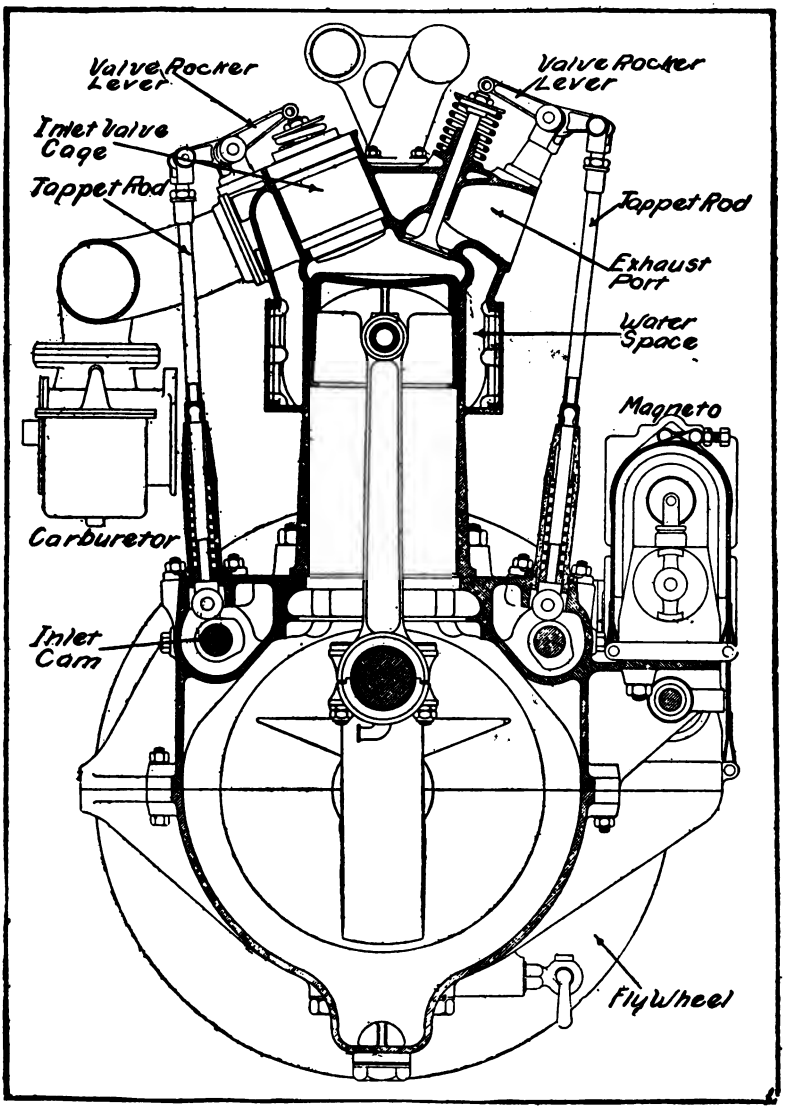


Fig. 25.—Sectional View Through Cylinder and Crank Case of Benz Racing Motor Showing Valve-in-the-Head Construction.

Q. What is the advantage of "valve-in-the-head" construction?

A. When the valves are placed so that they open directly into the combustion chamber it is possible for the gases to flow with less friction on account of the direct passages and a combustion chamber is provided which has greater efficiency as regards heat losses than either the "L" or "T" form. (Figs. 25 and 26.)

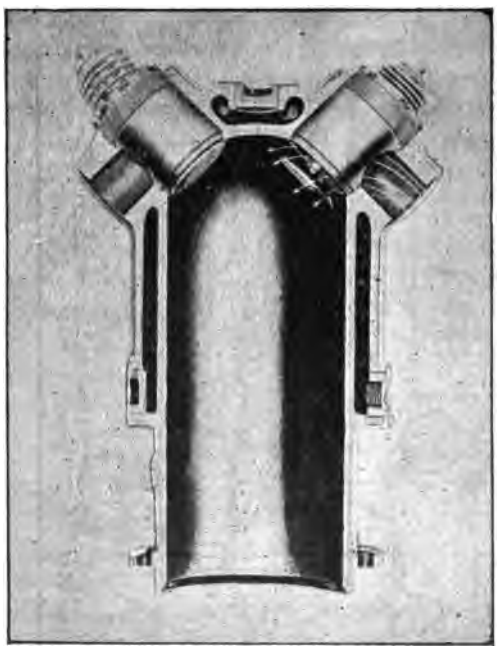


Fig. 26.—Sectional View of Individual Cylinder Casting with Valves-in-the-Head.

Q. What determines sizes of valves?

A. Valve sizes are determined by the cylinder volume and by the speed at which the engine operates. High speed engines require larger diameter valves in proportion to the cylinder bore than do low speed engines. The form of the cam and shape of the valve head also have a bearing on the size of the valve.

Q. Name forms of mushroom valves.

A. Mushroom valves may have either a flat seat (Fig. 28) or a beveled seat (Fig. 30). They are usually a one-piece construction and are machined from a forging of nickel steel. Sometimes the head is of one material, such as a 35% nickel steel, electrically welded to a carbon steel stem. Valves are sometimes made with a head of cast iron which is attached to the steel stem by riveting the end of the stem over after the cast piece is forced on the upper end.

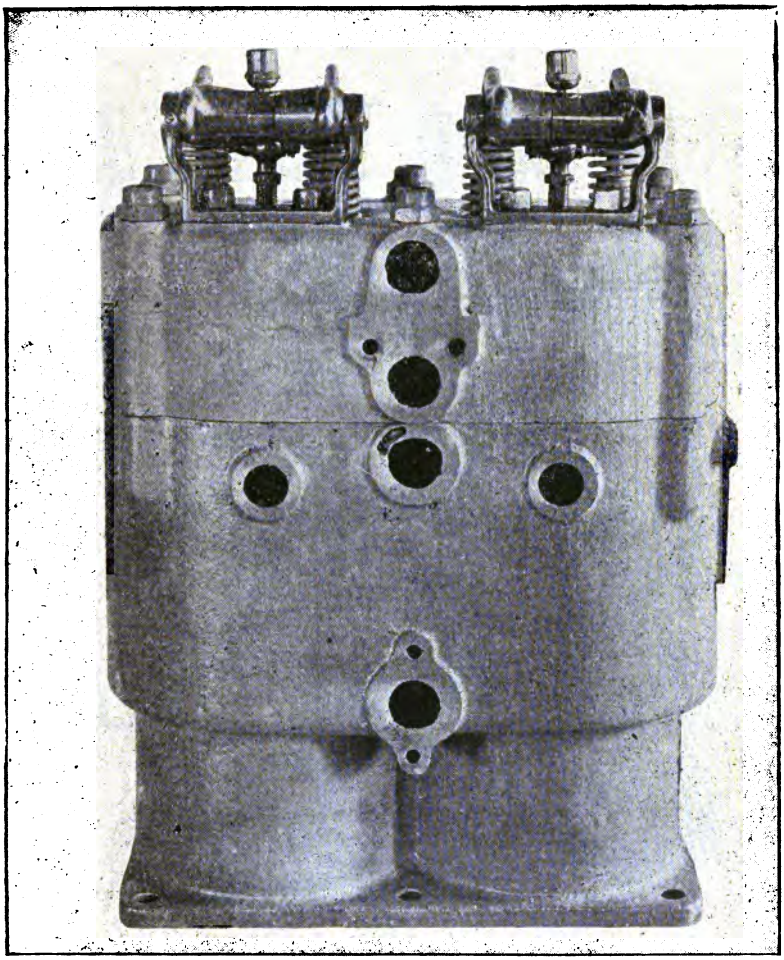


Fig. 26A.—Cylinder Pair of Knox Engine With Valves-in-the-Head.

Q. Are other forms of valves practical?

A. A number of other forms of valves have been developed recently that differ radically from the mushroom form. These have given satisfactory service in some instances.

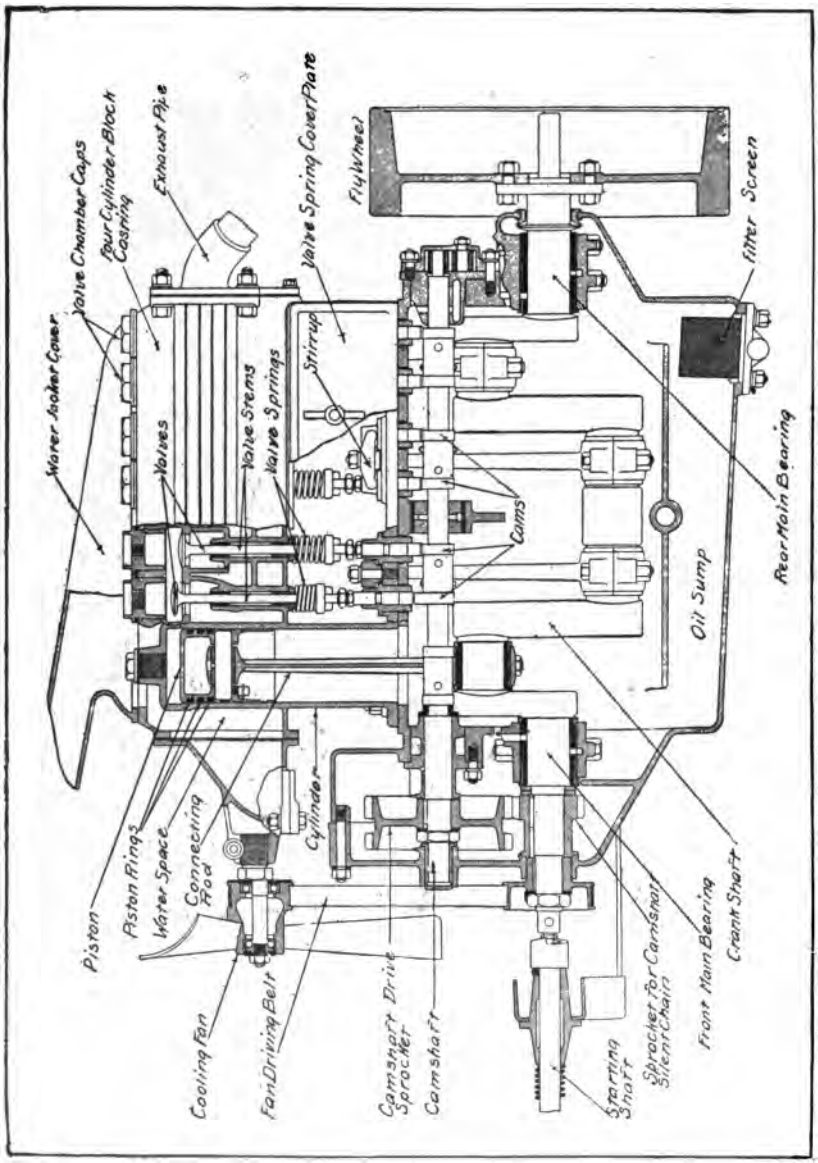


Fig. 27.—Sectional View of Four-Cylinder Motor Having the Cylinders Cast in Block and Using a Two-Bearing Four-Throw Crankshaft.

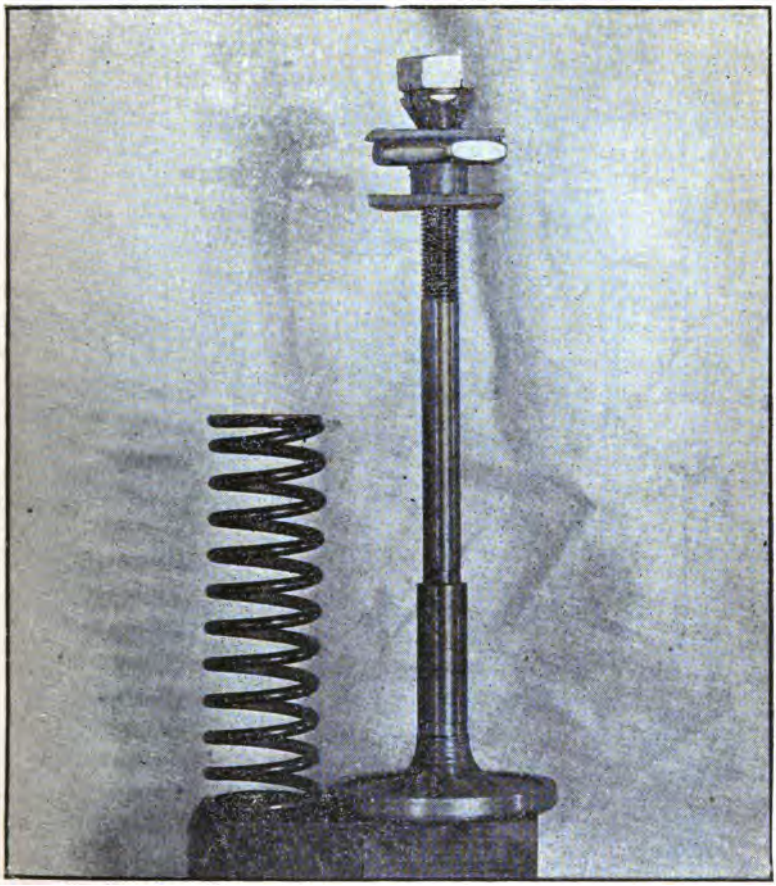


Fig. 28.—Typical Flat Seat Valve and Spring.

Q. Name the other systems of valve construction.

A. The other forms of valves that have been evolved to replace the poppet type usually consist of some rotating or sliding member that uncovers ports, through which the gases pass.

Q. What is the Knight engine?

A. The Knight engine, which is illustrated at Figs. 31 and 32,

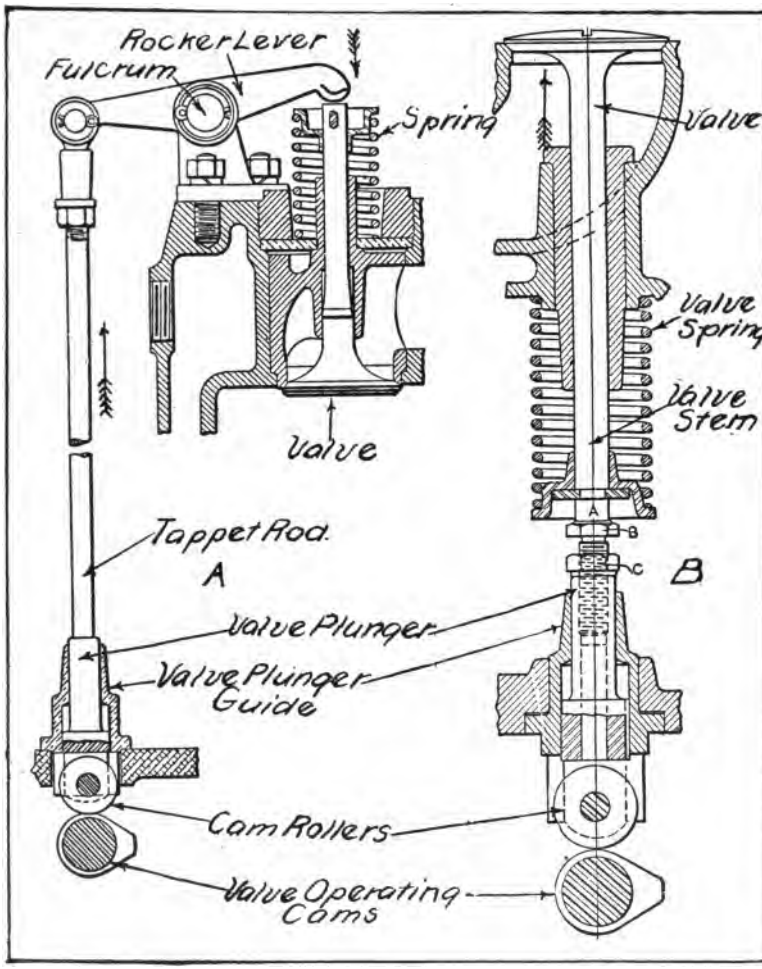


Fig. 29.—Conventional Methods of Operating Internal Combustion Motor Valves. A—Valve Actuated by Rocker Lever and Tappet Rod. B—Valve Operated by Simple Plunger Resting on the Cam.

operates on the four-cycle principle and has two sliding sleeves which are placed inside the cylinder and interposed between the cylinder wall and the piston. These are given an up and down movement by small connecting rods attached to the sleeve at one

end and a small auxiliary crankshaft at the other These sleeves uncover ports which are formed in the cylinder walls.

Q. What are rotary valves?

A. Rotary valves are forms in which the ports in the combustion chamber are opened by a revolving cyl nder or disc at a certain portion of its revolution.

Q. Describe action of typical rotary valve.

A. The Mead rotary valve motor utilizes a cylinder of metal placed at the side of the combustion chamber and driven at one-quarter the crankshaft speed by means of silent chain gearing. One of these cylinders is carried at each side of the cylinder blocks, one serving to admit the gases into the combustion chamber, the other to provide means for their discharge. The operation of this orm of valve is very simple. A series of slots are mach ned in the revolving valve member and at the proper points in the cycle of operation these register with suitably formed ports in the combustion chamber and manifold respectively. (Figs. 33, 35.)

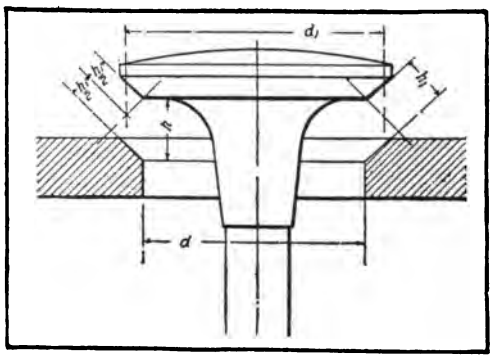


Fig. 30.—Outlining Design of Typical Bevel Seat Motor Valve.

Q. What are piston and ring valves?

A. In ome engines a sliding member or piston is used to uncover ports in the cylinder walls as shown at Fig. 36 A or a reciprocating ring may perform the same function as in the Sphinx motor depicted at Fig. 37.

Q. What is a simple rule for size of inlet valve?

A. The effective area of a valve port when the valve is fully opened should be a little greater than the size of the passage of pipe through which the gases enter the cylinder. The size of the intake passage as determined in usual engine practice may be found as fol ows:

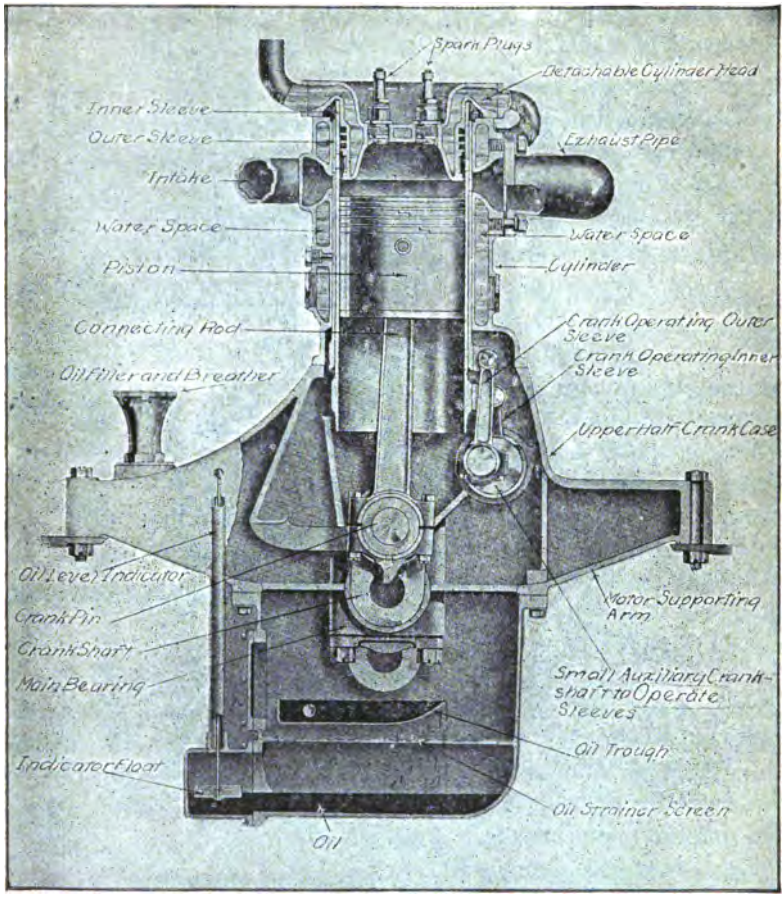


Fig. 31.—End Section of Knight Engine Showing Sliding Sleeves Which Replace Poppet Valves for Controlling Gas Passages.

1. The diameter of the passage is equal to that of the piston multiplied by .30 on slow speed engines and by .40 on high speed motors. 2. The area of the inlet passage is equal to one-eighth the area of the piston. 3. Intake passage area should equal area of piston multiplied by the speed of the piston in feet per minute and then divided by 5000.

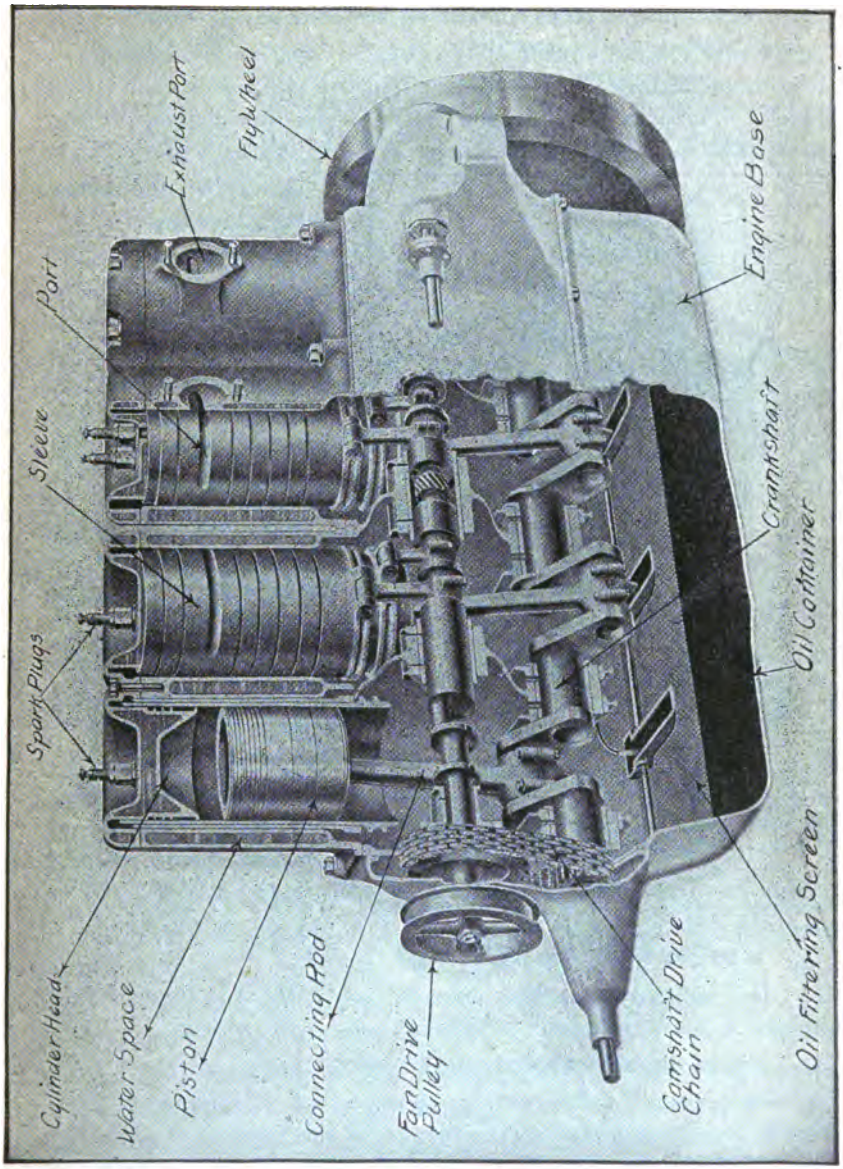


Fig. 32.—Partial Side Sectional View of Knight Sleeve Valve Engine Showing Interior Mechanism.

Q. Name simple rules for size of exhaust ports.

A. Usually the diameter of the exhaust port equals that of the piston multiplied by .35 on low speed engines and .50 on high speed engines. The area of the exhaust passage should equal that of the piston multiplied by the speed and divided by 5000 as a minimum.

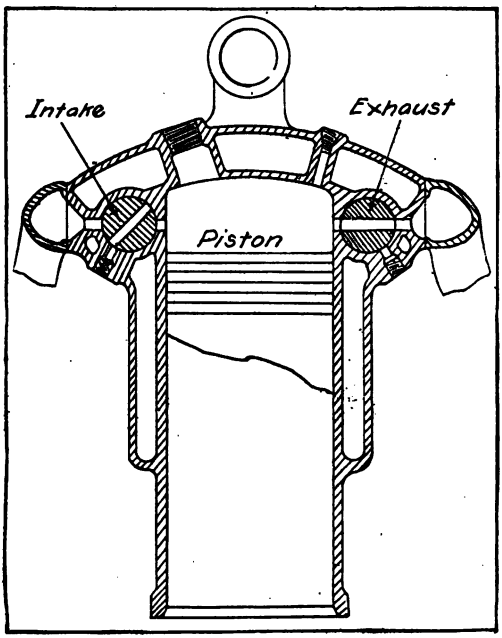


Fig. 33.—Sectional View of Cylinder Utilizing Mead Rotary Valve.

Q. When should the inlet valve open?

A. The inlet valve should open from ten to fifteen degrees crank travel after the piston leaves its innermost position in the cylinder.

Q. When should the inlet valve close?

A. The inlet valve closes from fifteen to thirty-five degrees after the piston starts to go up on its compression stroke.

Q. What is meant by valve lead?

A. If a valve opens before the piston starts on the stroke corresponding to valve opening, the valve is said to open early or to have lead.

Q. What is meant by valve lag?

A. If a valve opens late or remains open after it is theoretically supposed to close, it is said to have lag.

Q. When should exhaust valve open?

A. The exhaust valve usually opens about 45 degrees as indicated by crank travel before the piston reaches the end of its power stroke. In this case the exhaust valve has a lead of 45 degrees.

Q. When should the exhaust valve close?

A. The exhaust valve is usually allowed to lag about 10 degrees after the piston reaches the end of its scavenging stroke.

Q. What is the actual duration of inlet stroke?

A. The period during which the inlet valve remains open varies according to the lag at the time of opening and closing. If the valve opens 15 degrees late and closes 35 degrees after the piston has started up on its compression stroke it has remained open a period equal to 200 degrees crankshaft travel. If it opens promptly on top center and closes on bottom center it would only remain open a period equal to 180 degrees crank travel or half a revolution of the flywheel.

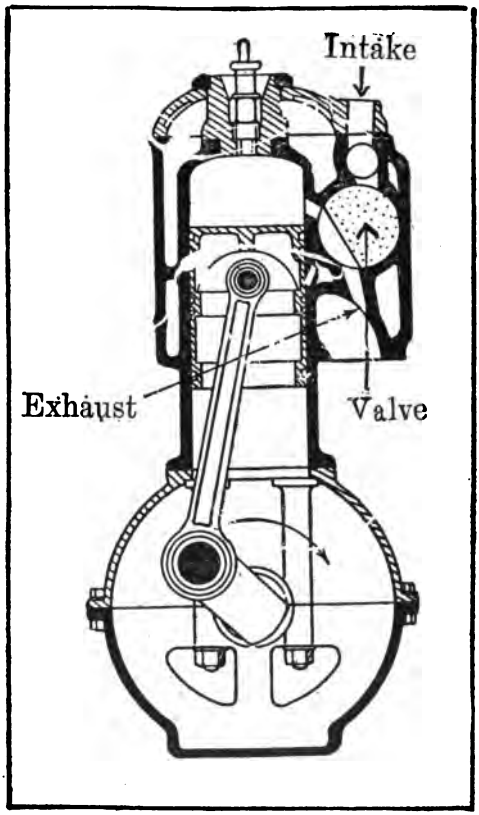


Fig. 34.—End View of Cylinder Employing Darracq Rotary Valve.

Q. What is the actual duration of exhaust stroke?

A. The exhaust valve usually remains open a period equal to a crank travel of 235 degrees.

Q. Why is exhaust valve opened early?

A. The exhaust valve is opened before the piston reaches the bottom of its power stroke because the gas contained in the cylinder has considerable pressure and will tend to fly out of the cylinder

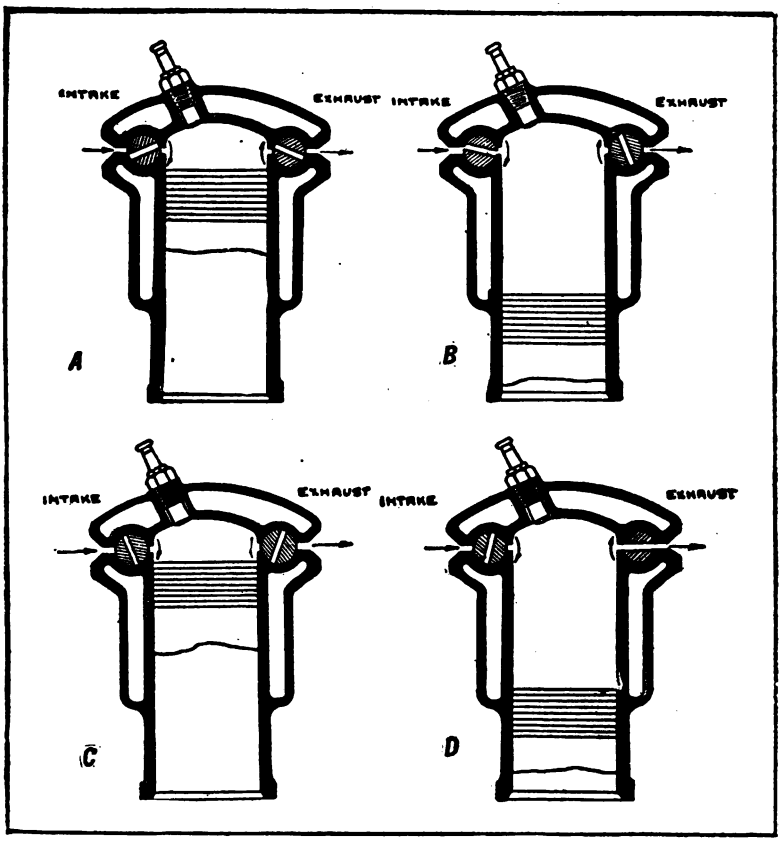


Fig. 35.—Outlining Action of Mead Rotary Valve Motor. A—Exhaust Valve Just Closed, Intake Valve Just Opening, Piston at Beginning of Suction Stroke. B—Piston at Bottom of Stroke, Inlet Passage Just Closing. C—Piston at End of Compression Stroke, Both Valves Closed. D—Piston at Bottom of Explosion Stroke, Exhaust Passage Fully Opened.

because of its pressure even before the piston starts going up on a scavenging stroke. It is necessary to give this lead to exhaust on the high speed engines used as automobile power plants in order to insure thorough clearing of the cylinder by taking advantage of the pressure of the exhaust gases.

Q. Why is valve lag desirable?

A. When the piston reaches the top or bottom of its stroke, there is an appreciable period measured in degrees as the crank swings over its center position where the piston movement relative to the crank travel is comparatively small. If the valves are kept open during this period, more gas can enter or leave the cylinder than would be the case if the valve closed promptly when the piston reached the top of its stroke. The rapidly moving gas acquires a certain momentum which is taken advantage of by keeping the valve open as long as possible.

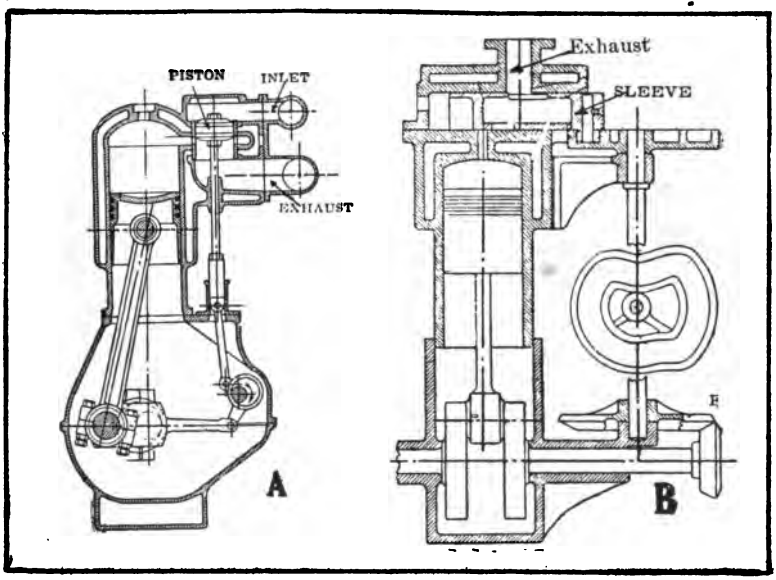


Fig. 36.—Outlining Construction of Piston and Slide Valve Motors of European Origin. A—Reciprocating Piston Controls Inlet and Exhaust Passages. Note Peculiar Valve Actuating Mechanism. B—Slide Valve Operated by Face Cam Driven From Motor Crank Shaft by Bevel Gears.

Q. How can one time valves easily?

A. A very simple method of valve timing is outlined at Fig. 39 which shows the manner in which the various points at which valves open and close are indicated on the face of the flywheel rim. All circles may be divided into 360 parts. Each of these parts is called

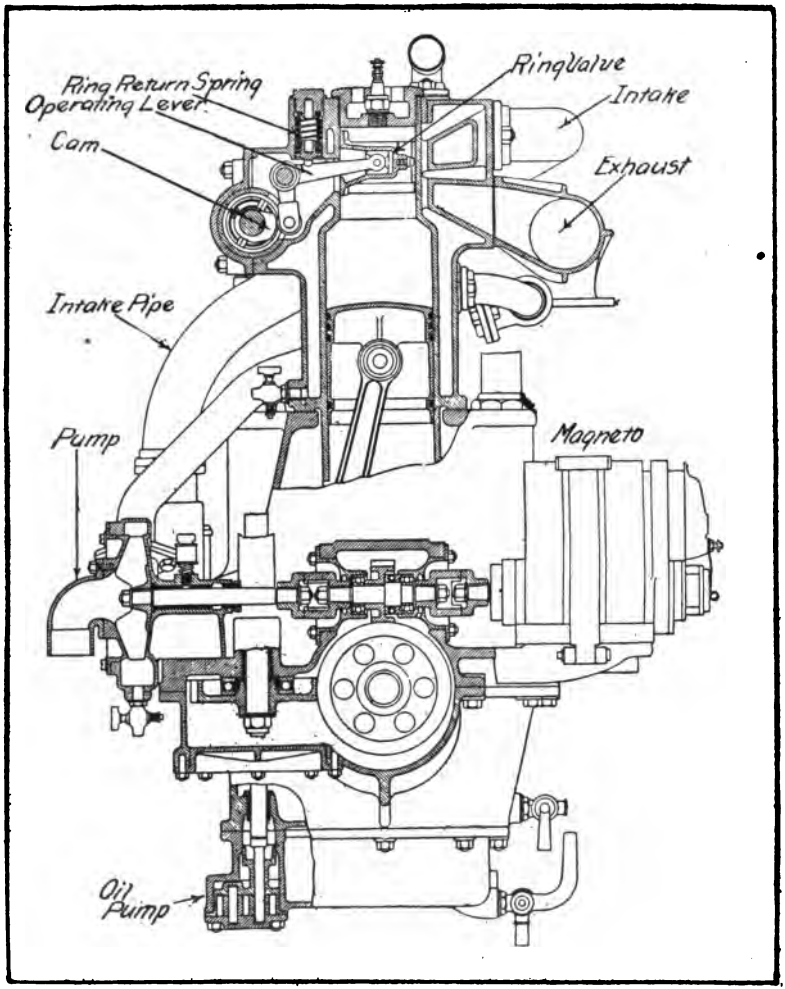


Fig. 37.—Sectional View of Cylinder of Sphinx Motor, which Utilizes Sliding Ring Valve.

a degree. If the diameter of the flywheel is known its circumference can be obtained by multiplying the diameter in inches by 3.1416. If the circumference is then divided by 360 the distance or portion of the flywheel circumference equivalent to one degree may be easily computed. The first operation is to bring the piston in one of the

cylinders, usually that of the first or fourth, to its uppermost position at the end of the compression stroke. A point is then indicated on the flywheel which will register with the vertical center line of the engine. This indicates the firing point for two of the cylinders of a four cylinder engine, though obviously one fires during one revolution of the flywheel, while the other explodes a complete revolution after. In the example indicated the flywheel is 18″ in diameter. A crank travel of 15 degrees is equal to $2\frac{1}{32}$″ measured on the flywheel circumference. Forty-five degrees, which is the lead of the exhaust valve, is equivalent to a distance of $7\frac{1}{8}$″. The lag of inlet closing or 35 degrees is equal to a distance of $5\frac{1}{2}$″ while the lag of exhaust closing or 10 degrees is equal to $1\frac{9}{16}$″. It will be evident

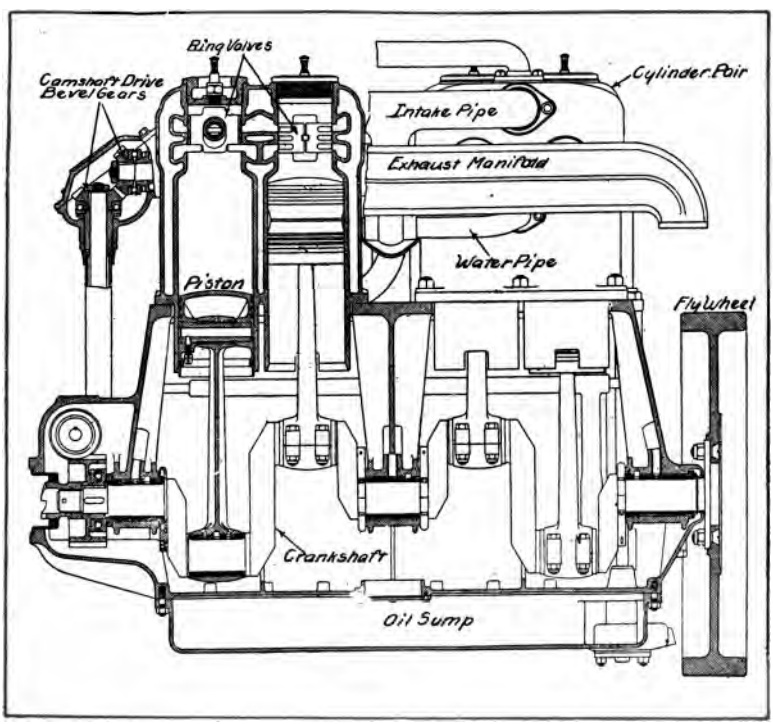


Fig. 38.—Side Sectional View of Sphinx Motor Showing Peculiar Annular Exhaust and Intake Passages and Ring Valve Controlling the Admission and Expulsion of Gas.

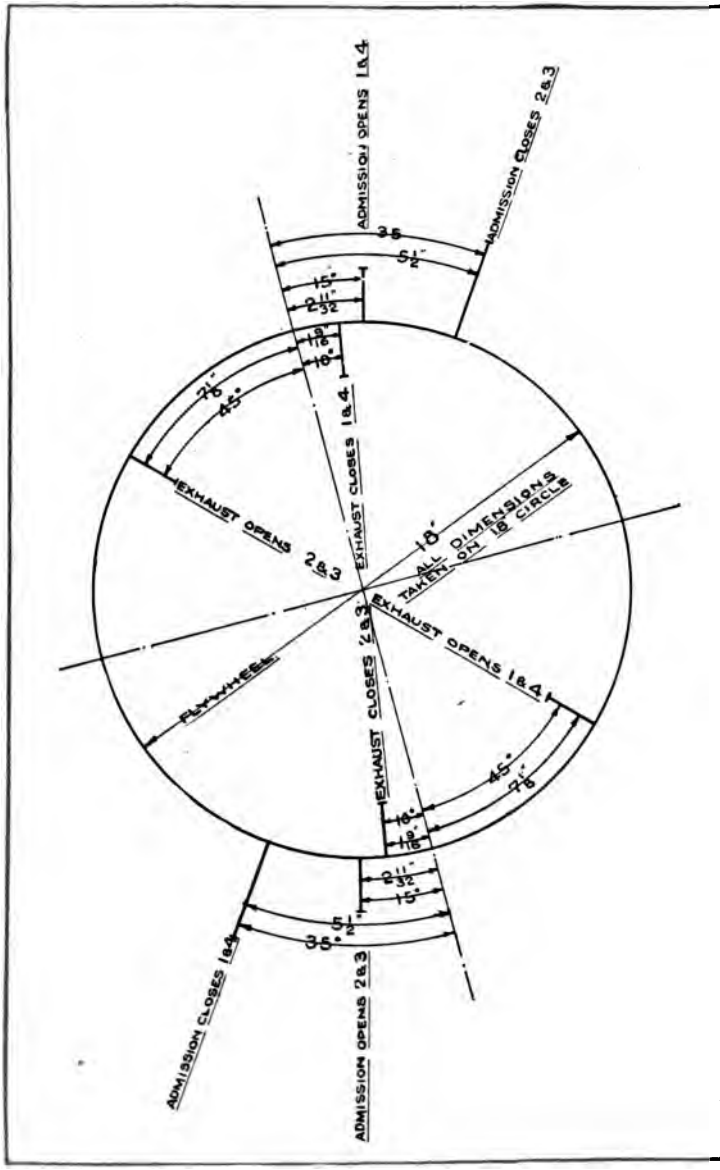


Fig. 39.—Valve Timing Diagram Showing Spaces Laid Out on Flywheel, the Dimensions Given Corresponding to the Number of Degrees of Crank Shaft Movement. The Dimensions Indicated in Inches are Only Suitable for Flywheel 18 in. in Diameter, though the Timing in Degrees May Be Used as a Guide for Many Four-Cylinder Motors.

that the valves may be timed to open and close very accurately if the engine flywheel is provided with the proper marks and a suitable trammel or other indicator is placed on the engine base to indicate the center line of the engine.

Q. What is the camshaft?

A. The small auxiliary shaft that carries the valve lifting cams and usually runs parallel with the crankshaft and which is driven by that member is called the camshaft. Some engines have but one camshaft, which carries the cams utilized in operating both inlet and exhaust valves. The "L" type cylinder engine needs but one camshaft while the power plant provided with "T" head cylinders needs two camshafts, one at each side of the motor. (Figs. 23 and 24.)

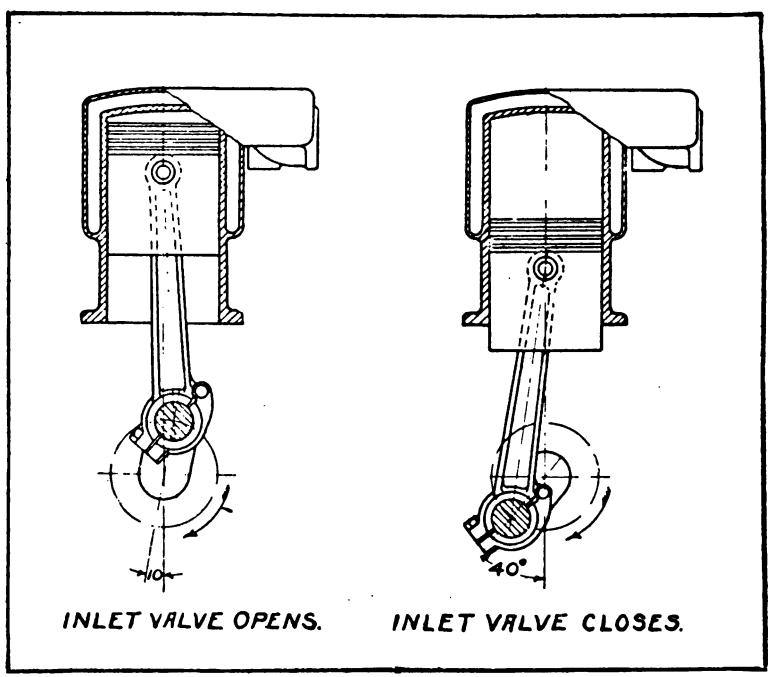


Fig. 40.—Showing the Time of Opening and Closing of Inlet Valve Relative to Crankshaft Travel.

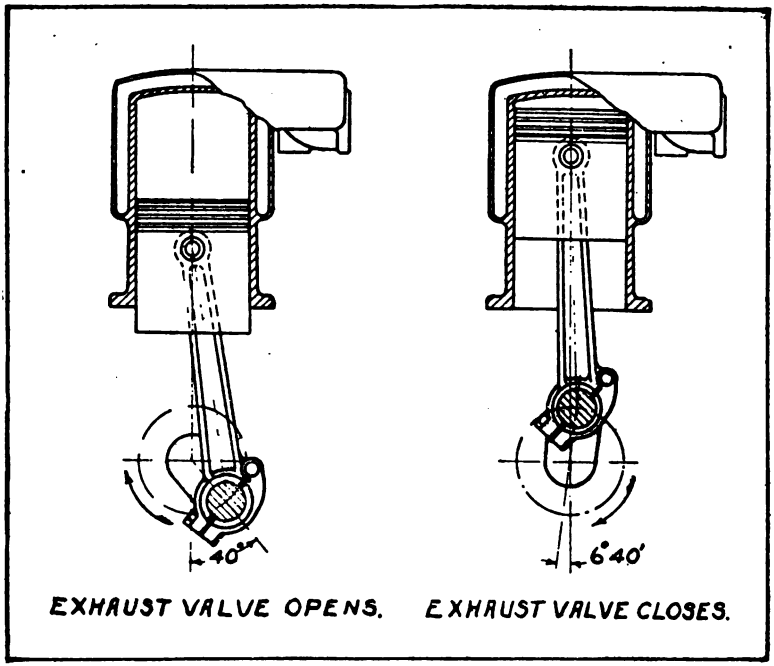


Fig. 41.—Outlining Position for Opening and Closing Exhaust Valves.

Q. How is the camshaft driven?

A. The camshaft may be driven by means of gearing as shown at Fig. 42 or by silent chains as outlined at Fig. 43.

Q. At what speed is the camshaft driven?

A. The camshaft of a four-cycle engine is always driven at half the engine speed and always by positive gearing.

Q. What is a cam?

A. A cam is a cylinder of metal having a raised portion at one point on its periphery.

Q. What is the difference between inlet and exhaust cams?

A. The difference between inlet and exhaust cams is in the cam profile as the member intended to lift the exhaust valve has a longer dwell or larger and longer raised portion because the exhaust valve is kept open longer than the inlet member.

Q. How are cams attached to the camshaft?

A. The cams may be separate forgings assembled on a piece of straight shaft and held from turning by means of keys and taper pins driven through both cam and shaft. Or they may be formed integrally with the camshaft by either a forging or machinery process.

Q. How do cams raise the valves?

A. The point of a cam raises the valve stem through the medium of a plunger or cam follower which rides on the cam and follows the profile. As will be seen at Fig. 44, when the point of the cam is not in contact with the roller on the valve operating plunger, that member

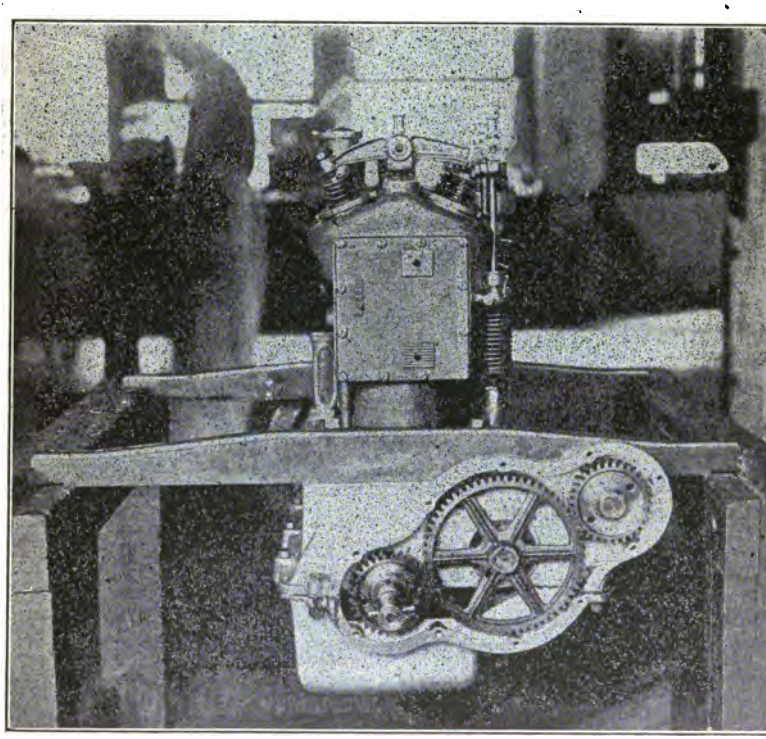


Fig. 42.—Front View of Engine Showing Gearing for Operating Cam Shaft.

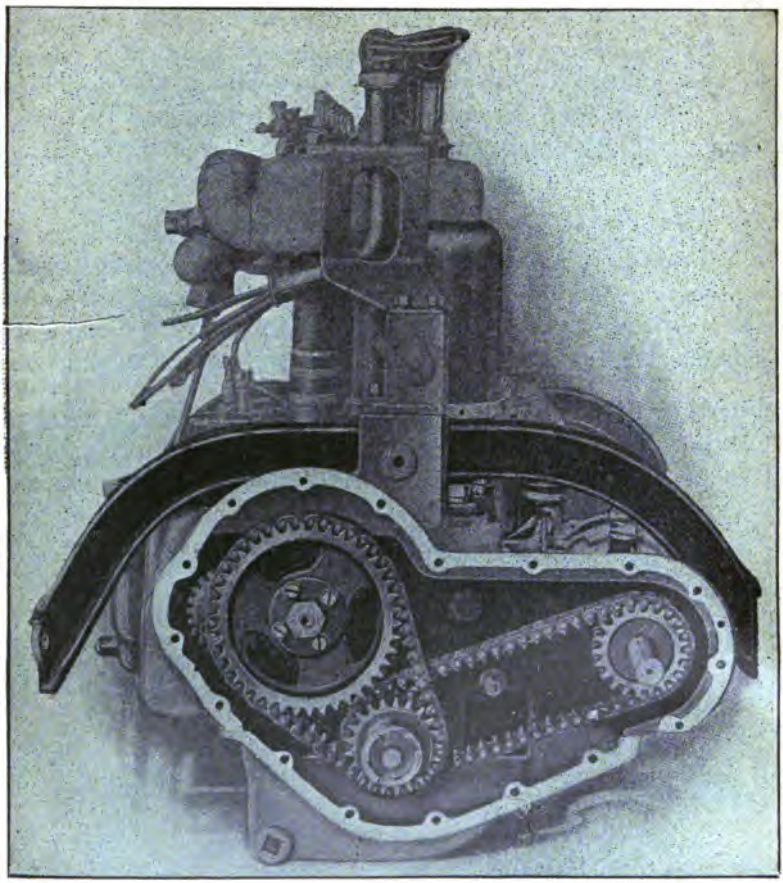


Fig. 43.—Front View for Cadillac Motor Showing Silent Chain for Camshaft and Water Pump Drive.

projects down and is nearly in contact with the circular portion of the cam profile. As soon as the projection moves around so that it hits the roller, that member is raised and rides over the projecting nose of the cam, thereby raising the valve plunger and the valve that it operates.

Q. **What is the best form of valve plunger?**

A. The best form of valve plunger to use depends entirely upon

cam profile. The preferred construction is to use a hollow tubular member, to secure lightness, provided with a hardened roller at its lower end that follows the cam contour with a rolling motion. Where the cam construction permits a mushroom plunger is sometimes emp'oyed.

Q. How are valve plunger guides fastened?

A. Valve plunger guides are attached to the engine base by any one of three commonly used methods. That most widely applied is

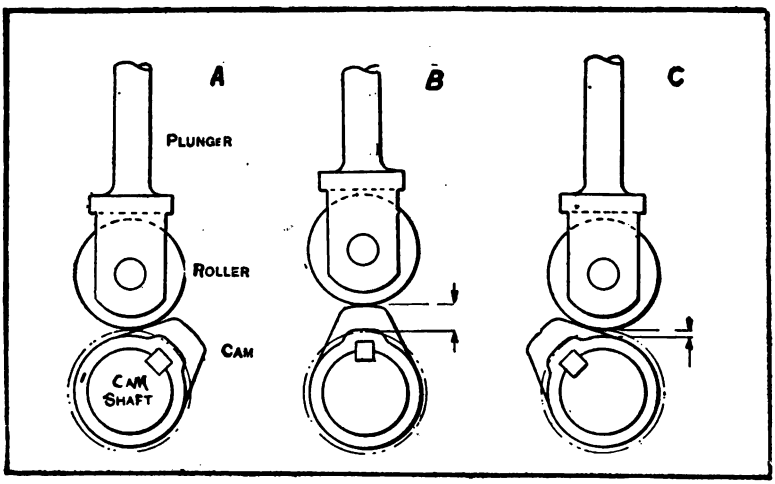


Fig. 44.—Defining Method by Which Valve Operating Cam Raises the Plunger Between Camshaft and Valve Stem. A—Plunger Just Engaging Point at Cam. B—Plunger Fully Raised. C—Plunger Leaving Point of Cam.

to bolt them down with small cap screws. Optional methods are the use of a stirrup or double yoke member which is held by one bolt and which holds two valve plunger guides or by screwing the guide bushings into suitable tapped holes in the engine base.

Q. What keeps the valves against their seats?

A. The valves are kept seated by means of coil springs which are under compression and which always oppose cam action.

Q. Which valve has the strongest spring?

A. The strength of the valve springs depends on methods of

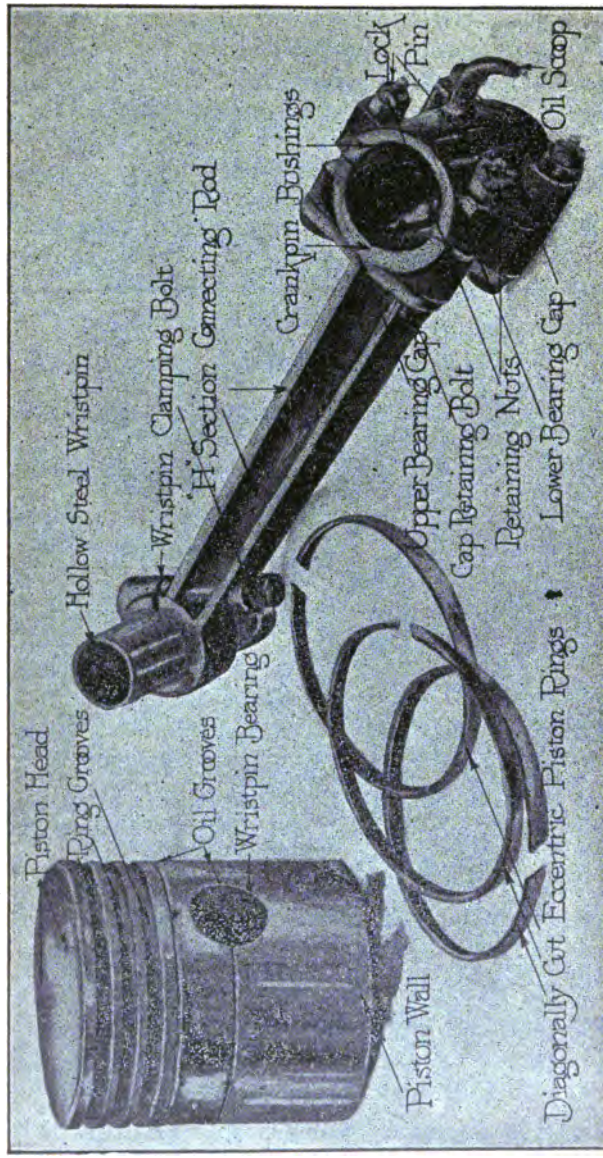


Fig. 45.—Piston, Piston Rings, Wrist Pin, and Connecting Rod of Typical Gasoline Motor.

valve operation. If the inlet valve is operated by suction only, the spring is comparatively light and the exhaust valve has the strongest spring. When mechanical valves are employed and both are the same, the exhaust and inlet valve springs are of equal strength to facilitate replacement and to make them interchangeable during manufacturing.

Q. How strong should valve springs be?

A. Valve springs should be just strong enough to hold the valve firmly against its seat and to return it to a closed position at the maximum speed of the motor just as soon as the cam roller leaves the raised portion of the valve operating cam. If valve springs are too strong, considerable power will be consumed in raising them, whereas if too weak the valve operation and consequently the engine action will be erratic.

Q. Name advantages of enclosed valve gear.

A. On modern motors the tendency is to enclose the valve operating plungers and springs in chambers formed in the cylinder castings by means of cover plates. This is desirable practice because it keeps dirt and grit away from the valve operating plungers and valve stems and insures superior quietness of operation. (Fig. 23.)

Q. What is the piston and of what material is it made?

A. The piston is a reciprocating cylindrical member that moves in the cylinder and which transforms the power of the explosion to mechanical energy. Pistons are usually made of close grained gray iron of approximately the same mixture as the cylinder iron though where great lightness is desired, as on aeroplane motors, steel may be employed. (Fig. 45.)

Q. What are the piston bosses?

A. The piston bosses are projections cast inside of the piston to hold the wrist pin or member that supports the upper end of the connecting rod. (Fig. 46.)

Q. What are the piston rings?

A. A piston is usually provided with a series of grooves in which rings of cast iron are mounted to form a packing. The piston must

be a free fit in the cylinder in order that it will not expand unduly when heated and bind. For this reason the packing rings are depended upon to keep the exploding gases from leaking by, and as they have considerable elasticity they conform to the cylinder bore and fit it very closely. As they are narrow they do not have much bearing surface on the cylinder and do not offer undue friction if properly lubricated. The piston rings are usually placed at the top of the piston, as shown at Fig. 45, though in rare instances they have been applied to the bottom of the piston, as outlined at Fig. 46.

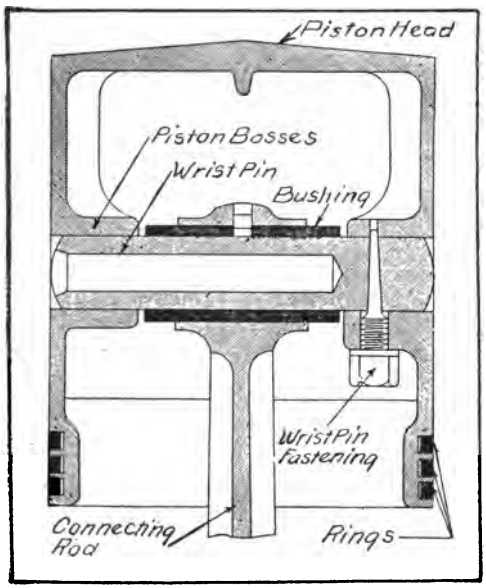


Fig. 46.—Unconventional Piston of English Design With Piston Rings at the Bottom.

Q. Name common form of piston rings.

A. The piston rings may have a uniform thickness at all points and the inside be concentric with the outside or they may be thinner at one side than the other and the inner circle of the r ng be placed eccentrically in relation to the outer periphery. The eccentric ring is the type more generally used, as it is bel'eved to have a more uniform expansion when heated than the concentric form. The piston ring is always thinnest at the point where it is split.

Q. Why are piston rings split?

A. Piston rings are split for two reasons, the most important being to obtain sufficient elasticity so that they may be sprung in place in the piston grooves and also that they may expand sufficiently to take up the space existing between the piston and cylinder walls.

Q. Why are piston rings carefully machined?

A Piston rings are carefully machined so they will be true to cylinder bore and fit the grooves of the piston accurately and at the same time they must have a smooth surface where they contact with the cylinder walls in order to reduce friction to a minimum. After piston rings have been in use for a time the surface becomes covered with a hard glaze and there is practically no friction between the ring and the cylinder.

Q. What is the difference in size between piston diameter and cylinder bore?

A. The piston is always made smaller than the cylinder by a few thousandths of an inch. The difference between diameter and bore is regulated by the size of the engine and the methods of cooling employed. On ordinary automobile engines the piston has three diameters, being smallest at the top and largest at the bottom. The amount of taper of the piston walls is so slight that it is not noticeable except with delicate measuring instruments. The piston of a five inch bore engine would be .007″ smaller at the top than the cylinder or 4.993″ in diameter. At the middle point approximately on the center line of the piston bosses the piston would be 4.995″ in diameter or .005″ smaller than the cylinder bore. At the bottom the piston would be about .003″ smaller than the cylinder bore.

Q. Why is this difference in size necessary?

A. The piston is made smaller than the cylinder bore in order to prevent friction between piston and cylinder walls as they become heated in operation and to provide a space between the reciprocating and fixed members or an oil film

Q. What is the wrist pin?

A. The wrist pin is a short bar of steel of circular or tubular cross section placed between the two piston bosses to which the upper or small end of the connecting rod is fastened.

Q. How is the wrist pin secured in piston bosses?

A. The wrist pin is usually a push fit in the piston bosses and is kept from moving out of place by some form of lock which passes through both piston boss and wrist pin. The simplest form of lock

is a common set screw which bears against the wrist pin or some form of taper pin or split cotter, passing through the piston bosses into the wrist pin interior. (Fig. 46.)

Q. What is the connecting rod?

A. The connecting rod is the member that forms the connecting link between the reciprocating piston and the rotary crankshaft. It describes a rotary movement at its lower end and oscillates at its upper end. (Fig. 47.)

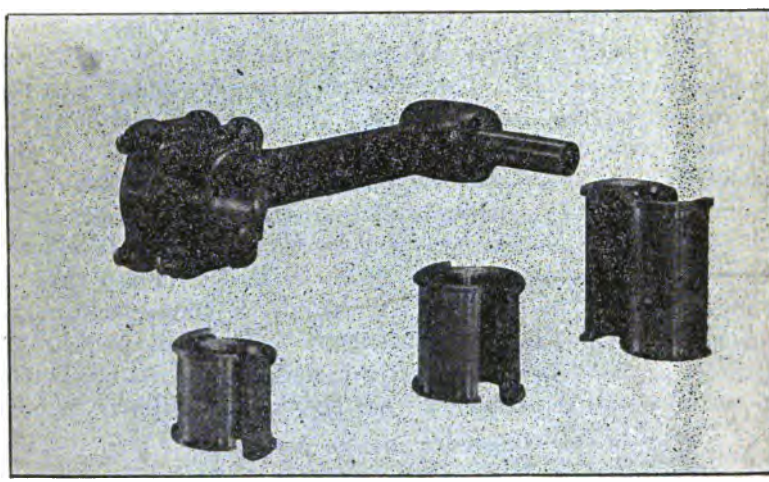


Fig. 47.—Connecting Rod Assembly and Bushings Used on Crank Shaft Main Bearings.

Q. What determines connecting rod length?

A. The length of the connecting rod depends entirely upon the stroke of the engine. Long stroke motors have longer connecting rods than short motors. A connecting rod is usually equal to 2.5 times the stroke of the piston in length.

Q. What materials are used in connecting rods?

A. Connecting rods are invariably made of steel drop forgings at the present time, though formerly steel, bronze, and even malleable iron castings were used.

Q. Name two common connecting rod types.

A. The common forms of connecting rods used on automobile motors are shown at Fig. 48. That at *A* is known as the marine type and the lower cap is an entirely separate member from the connecting rod proper and is attached thereto by means of two or four bolts. The form outlined at *B* is a modified marine type and in this the lower cap is hinged at one side and attached by means of a bolt at the other. (See also Figs. 45, 47.)

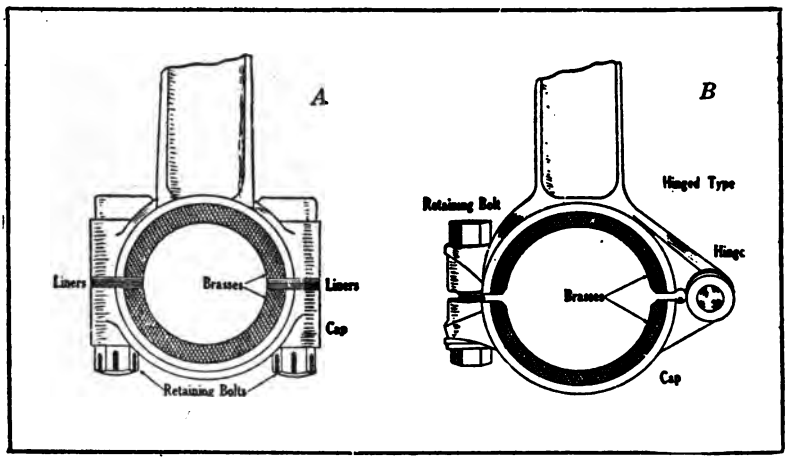


Fig. 48.—Outlining Method of Constructing Connecting Rod Big Ends. A—Marine Type with Completely Removable Cap. B—Hinged Type.

Q. What is the upper connecting rod bearing made of?

A. The upper connecting rod bearing is usually a bushing of hard bronze forced into the boss at that end of the connecting rod. It bears on and runs in connection with a case hardened steel wrist pin.

Q. What is the lower connecting rod bearing made of?

A. The lower connecting rod bearing, which encircles the crank pin of the crankshaft, is usually composed of some anti-friction metal, such as Babbitt on the cheap light engines or Parsons white bronze or similar alloy on the more expensive motors. On light en-

gines the Babbitt metal is often poured directly into the connecting rod lower end and the connecting rod cap. On high priced motors the alloy is made in the form of die cast bushings, one of which fits the connecting rod and the other the cap. Bronze brasses are also used sometimes. (See Fig. 47.)

Q. What means are provided to adjust bearings?

A. A number of shims or liners of thin metal, such as sheet copper or brass stock, ranging from .002″ to .006″ and sometimes thicker, are interposed between the upper and lower connecting rod

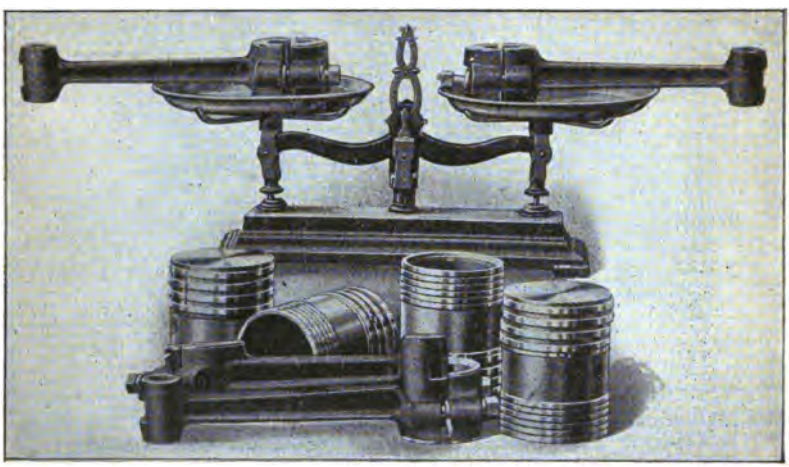


Fig. 49.—How Chalmers Pistons and Connecting Rods Are Weighed and Balanced So that Members Working in Unison Will Have the Same Weight and Assure Smooth Running of Motor.

members. After a certain amount of service, if the brasses, as the bushings are technically termed, wear so that there is appreciable looseness between the connecting rod and crank pins, one or more of these shims may be removed and the boxes brought closer together to compensate for the amount of wear. Sometimes one thick shim of fiber or brass is provided instead of the greater number of smaller ones, and this is thinned down by filing to decrease the distance between the brasses.

Q. Are plain bearings the only practical kind?

A. While plain bushings are more generally used on the connecting rod big ends and main journals of the crankshaft, anti-friction bearings of the ball or roller type have been used with some degree of success.

Q. What are the advantages of anti-friction bearings?

A. Anti-friction bearings, especially those of the ball type, turn much more easily than plain bushings and less power is consumed by bearing friction when they are employed. They are also more enduring than the plain journals, and when properly selected show absolutely no wear after extended periods of operation. (Fig. 50.)

Q. What is the accepted relation between cylinder bore and piston stroke?

A. The piston stroke of modern engines is longer than the diameter of the bore. Usually the piston movement is equal to about 1.25 times the diameter of the piston. The piston stroke in extreme cases may be 1.75 or 2 times the cylinder bore.

Q. What is a long stroke motor?

A. Any motor where the ratio of stroke to bore is greater than 1.5 to 1 is termed a "long stroke motor."

Q. What limits length of stroke?

A. The permissible length of stroke of the piston is limited by an arbitrary piston speed which it is not desirable to exceed because difficulties in lubrication and cooling are apparent at greater piston speeds than that established by common practice.

Q. Define "piston speed" and give commonly accepted limits.

A. The stroke of the piston in inches multiplied by 2 and this product multiplied by the number of revolutions per minute and this in turn divided by 12 will give the piston speed in feet per minute. An engine with a six inch stroke going at 1,000 R. P. M. will have a piston speed of 1000 feet per minute, which is the commonly accepted limit.

Q. Of two engines going at the same crankshaft speed will

the long stroke or short stroke engine have the highest piston speed?

A. The piston of the long stroke motor will obviously have the greatest piston speed. The shorter the stroke of an engine, the greater the number of revolutions its crankshaft can attain.

Q. What is the crankshaft?

A. The crankshaft is the part of the motor which converts the reciprocating motion of the piston to a continuous rotary movement suitable for driving the wheels of the automobile.

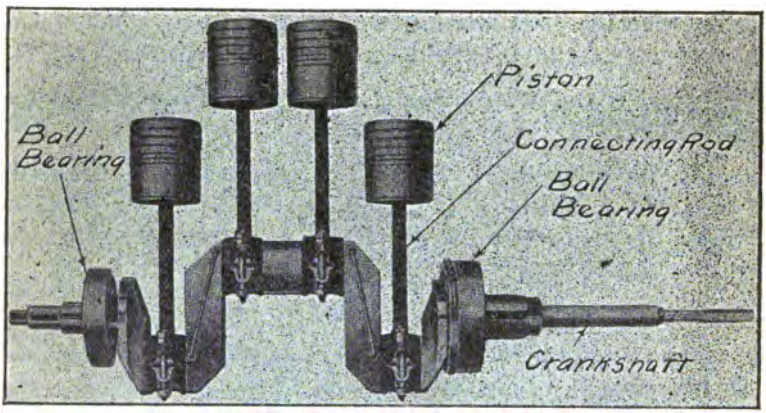


Fig. 50.—Showing Ball-Bearing Crankshaft of the Two-Bearing Four-Throw Type used in White Motors.

Q. What are crankshafts made of?

A. Crankshafts are invariably made of steel and are usually formed by the drop forging process which forges them out approximately to the correct form. Crankshafts employed on moderate priced engines are usually of carbon steel, while those utilized on high powered engines are made of chrome-nickel and other high tensile strength alloy steels.

Q. What is the relation between crankshaft throw and piston stroke?

A. The crankshaft throw, which is the distance between the center line of the crank pin and that of the crankshaft proper, is always half the piston stroke.

Q. Do all crankshafts have the same number of throws?

A. Crankshafts intended for multiple cylinder engines have more throws than simple forms intended for one or two cylinder engines.

Q. Are crankshafts always in one piece?

A. Crankshafts are not always made from one forging or piece of metal. They are sometimes composed of a number of distinct machined pieces fastened together by mechanical means. (Fig. 51.)

Q. Why are built-up crankshafts necessary?

A. On small single cylinder and two cylinder V engines, such as used for motorcycle propulsion, the connecting rod is usually formed in one piece and the crankshaft assembly must be completed after the connecting rod is in place on the crank pin. With a split connecting rod construction one piece crankshafts are employed, whereas when one-piece connecting rods are used it is necessary to use a built-up crankshaft.

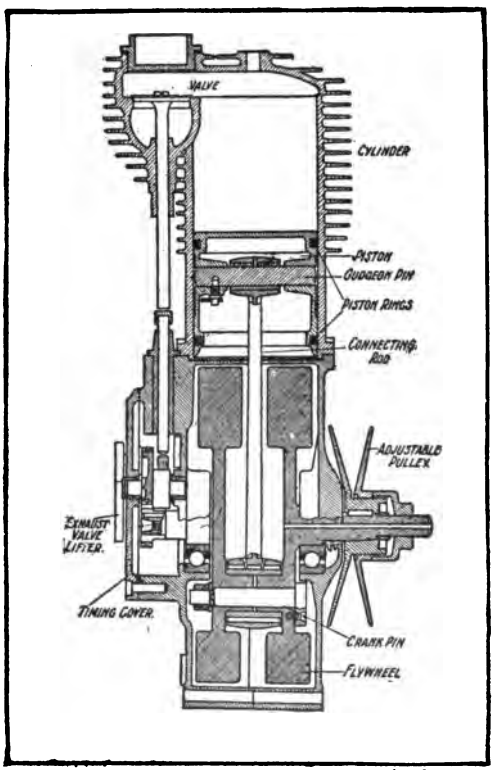


Fig. 51.—Sectional View of Typical Air-Cooled Motorcycle Engine Showing Built-up Crankshaft.

Q. What are counter weights?

A. Counter weights are fan shaped masses of cast iron attached to the crankshaft of single cylinder and some forms of two cylinder motors to balance the reciprocating weight of the pistons and a part of the connecting rods. (Fig. 52 A.)

Q. How are they attached to the crankshaft?

A. The conventional method of attaching counter weights is to bolt them to the crankshaft webs, though on built-up crankshafts used on motor cycle engines they are sometimes cast or forged integral with the flywheel members that correspond to the webs of the usual crankshaft and to which the crank pin is attached.

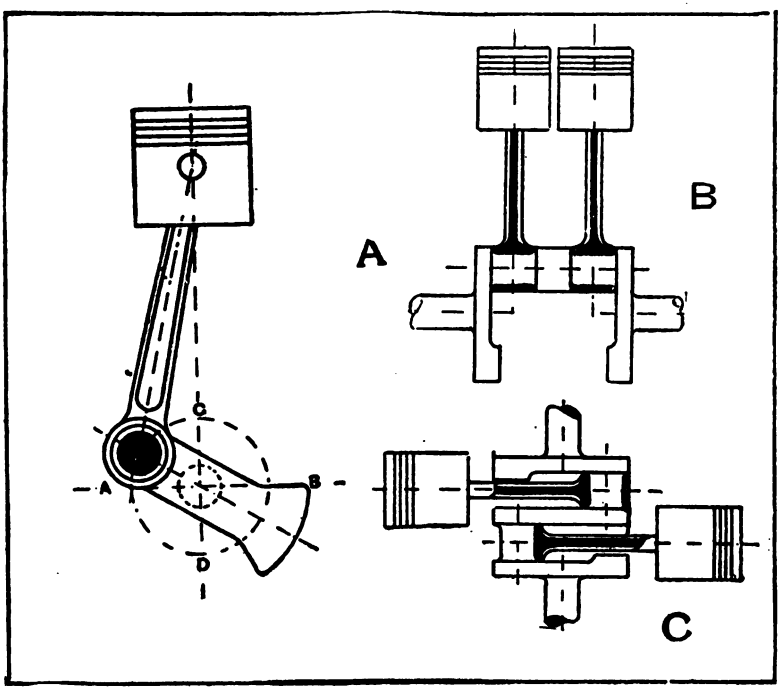


Fig. 52.—Showing Various Forms of One and Two Cylinder Crankshafts. A—Single Throw Crankshaft With Balance Weights. B—One-Throw Two-Cylinder Crankshaft With Balance Weights. C—Crankshaft for Two-Cylinder Opposed Motor.

Q. How are crankpins spaced in two cylinder engines?

A. Crank pins of two cylinder engines may be arranged in two different ways. In vertical engines both connecting rods may be attached to a common crank pin, as shown at Fig. 52 B, or they may be placed at 180 degrees or opposite each other, as shown at Fig. 52 C

and Fig. 53 A. When both crank pins are on the same plane in a two cylinder vertical engine it is possible to have the explosions follow in regular sequence, but the engine is not in correct mechanical balance. If the crank pins are spaced as outlined at Fig. 53 A, the engine is in better mechanical balance, but the explosions are not separated by regular intervals. The best method of utilizing two cylinders is to use a double opposed motor. In this case the crank pin arrangement is as shown at Fig. 52 C. Counter weights are necessary when both connecting rods act on the same crank pin, just as in a one cylinder engine.

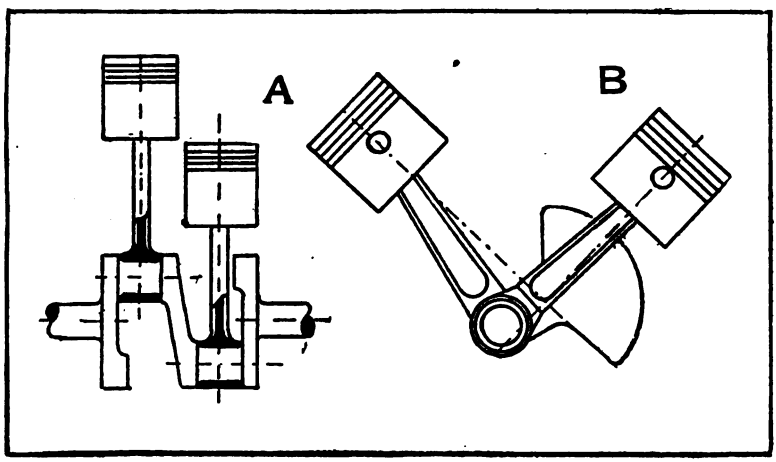


Fig. 53.—Unconventional Two-Cylinder Crankshaft. A—For Two-Cylinder Vertical Engine. B—For Two-Cylinder V Engine.

Q. How are the crankpins spaced in three cylinder motor?

A. Crank pins of a three cylinder motor are arranged on thirds of a circle or 120 degrees apart. (Fig. 54 A.)

Q. How are crankpins arranged on four cylinder crankshafts?

A. The conventional arrangement of crank pins on a four cylinder crankshaft is outlined at Fig. 54 B. Four separate crank throws are provided on two planes, spaced 180 degrees apart. The crank pins for connecting rods 1 and 4 are on a line and the pistons move up and down together. The crank throws of pistons 2 and 3 are on the same line.

Q. How are crankpins spaced on six cylinder engines?

A. The crank pins of six cylinder crankshafts may be arranged in two ways. The simplest arrangement is outlined at Fig. 54 C. In this three crank pins are provided, spaced 120 degrees apart, just the same as in a three cylinder crankshaft, each crank pin serving for two cylinders. The other method outlined at Fig. 54 D may be said to be composed of two three cylinder crank shafts joined together. The crank pins for cylinders 1 and 6 are on the same plane, the pistons of cylinders 2 and 5 move together, as is also true of the pistons of cylinders 3 and 4.

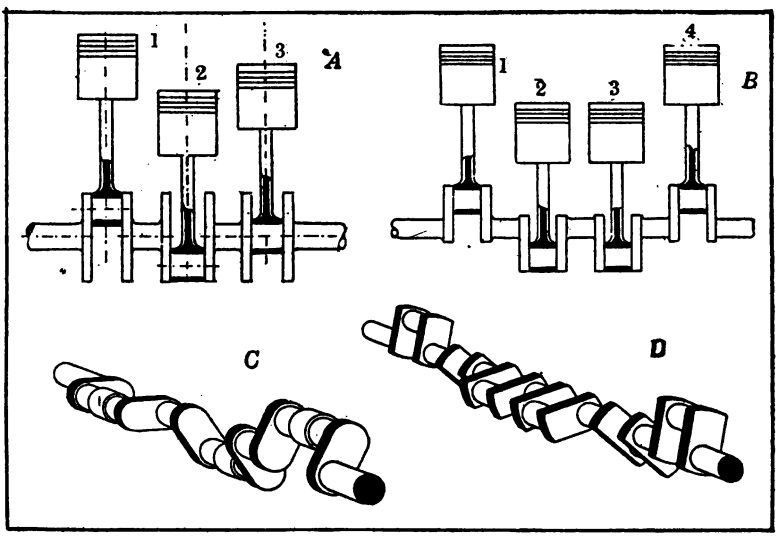


Fig. 54.—Outlining Construction and Arrangement of Throws of Crankshaft for Three, Four and Six-Cylinder Motors.

Q. How many main bearings on crankshaft?

A. The crankshafts of one, two, and some four cylinder motors have but two main bearings, one at each end. A three cylinder crankshaft usually has four main bearings. Four cylinder crankshafts used when motor cylinders are cast in pairs usually have three bearings, and when individual cylinder castings are used a four cylinder crankshaft will have five main bearings. Six cylinder crankshafts have either five or seven main bearings as a rule, though

on some very compact six cylinder engines a three main bearing crankshaft may be used.

Q. What is the influence of cylinder design on crankshaft length?

A. Motors employing block casings can have shorter crankshafts than those in which cylinders are cast in pairs or individually.

Q. What are crankshaft main bearings made of?

A. The crankshaft main bearings are generally made of the same material as employed for the bushings for the connecting rod big ends. Ball bearings have been used as main bearings and their use is more general in this application than it is in connecting rods. (Fig. 50.)

Q. What is the function of the crankcase?

A. The crank case is utilized to support the crankshaft and to act as a bed for the engine cylinders. It keeps the working part of the cylinder in perfect alinement with the crankshaft and camshaft carried and protected by the crank case and at the same time it serves as a carrying or supporting member by which the power plant is attached to the chassis.

Q. What are crankcases made of?

A. Automobile engine crankcases may be made of cast aluminum, cast iron, or bronze castings. The first named material is most generally used on account of its lightness. It has about the same strength as cast iron and weighs but one-third as much. On engines that are manufactured in large quantities, stamped sheet metal, such as steel and aluminum, have been utilized as the lower portion of the crank case.

Q. Name three common types of crankcase.

A. Crank cases may be divided into three types, the barrel form, the horizontally divided, and the vertically divided.

Q. What is the barrel type crankcase?

A. The barrel type is a form in which practically the entire crankcase is cast in one piece, end plates being provided for holding the main journals and also to cover the large openings in the ends of the crank case through which the crank shaft assembly is introduced.

Q. What are the advantages of the two piece crankcases?

A. When a two piece crank case is employed the lower portion serves merely as an oil container or cover and the crankshaft is supported by the upper half. When it is desired to adjust the main bearings or the connecting rod big ends the lower portion or oil pan of the crank case may be removed and the entire interior of the crank case is readily accessible. (Fig. 55.)

Q. How can interior parts of barrel type crankcases be reached?

A. Most forms of barrel type crankcases are provided with large openings or hand holes at the side which are closed by easily removable plates to permit of ready access to the crankcase interior.

Q. What is the function of the flywheel?

A. The flywheel is a heavy cast iron member attached to the crank shaft and is utilized to keep the crank shaft turning during the idle strokes by virtue of power stored in its rim during the working strokes of the motor. The one and two cylinder forms of engines require much heavier flywheels than four and six cylinder forms need. (Fig. 57.)

Q. What determines flywheel diameter?

The flywheel diameter is determined by the materials of which it is composed and by the speed of the crankshaft. A certain peripheral speed limit has been established for cast iron, which it is not desirable to exceed.

Q. Define peripheral speed.

A. The peripheral speed of the flywheel is the distance that any one point on its circumference covers in a given unit of time. Peripheral speed depends directly on the size of the flywheel and the number of revolutions at which it turns. For a given diameter the flywheel that turns the fastest has the greatest peripheral speed.

Q. What is safe peripheral speed for cast iron flywheels?

A. The safe peripheral speed for cast iron flywheels of ordinary construction is approximately 5000 feet per minute. A flywheel 5 feet in circumference could not turn more than 1000 R. P. M. without exceeding this limit.

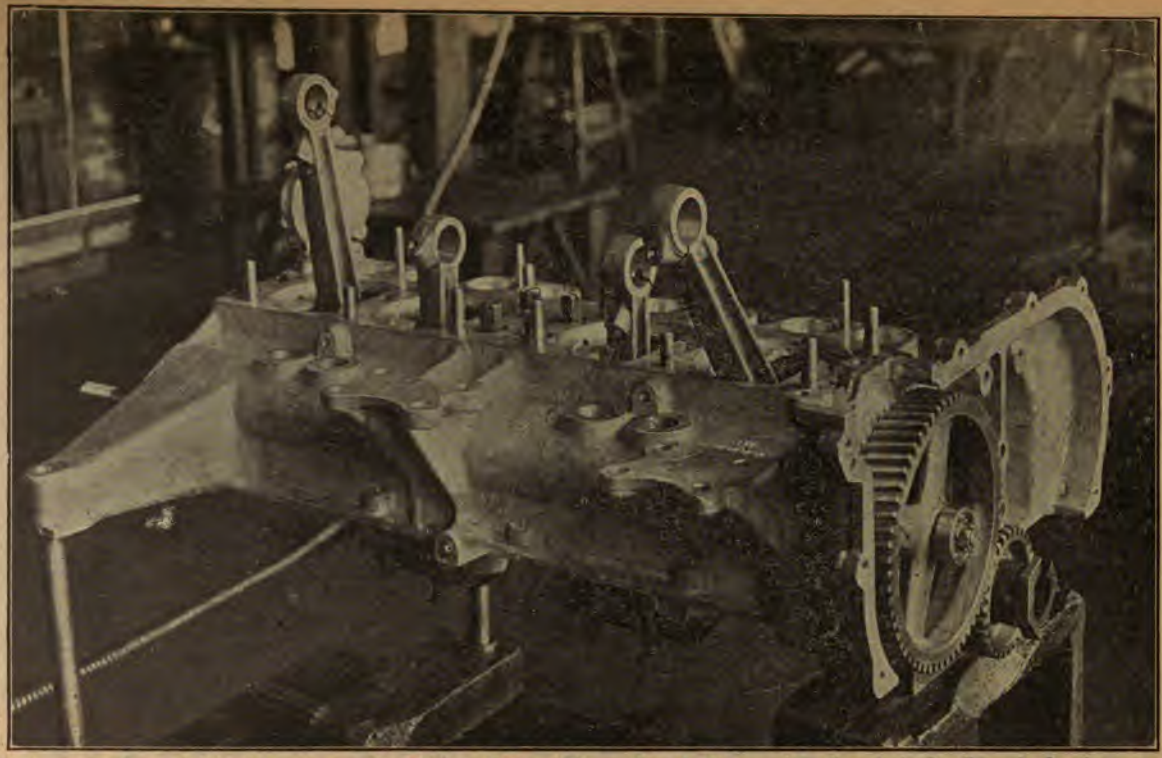


Fig. 55.—Top Half of Horizontally Divided Two-Piece Crank Case with Crankshaft, Camshaft, Operating Gears and Connecting Rods in Place.

Q. What can be done to increase flywheel speed without danger?

A. The flywheel may be made of a stronger material, such as steel, if it is desirable to retain the same diameter, or it may be made smaller in diameter if made of cast iron.

Q. Describe simplest type of flywheel.

A. The simplest form of flywheel consists of a web having a heavy rim or a simple cast hub joined to a heavy rim member by a series of radiating arms or spokes which are cast integral with the hub and the rim.

Q. What is the advantage of web wheels?

A. The web wheel is a safer method of construction and is also stronger than the spoke type. When a flywheel of the spoke type is turning at a high rate of speed it will do considerable injury to any object inadvertently thrust between the spokes. As the web construction makes practically a solid flywheel it is not possible to catch anything in the wheel.

Q. Why are flywheel spokes sometimes shaped like fan blades?

A. Fan blades are often incorporated in flywheels so that member acts as a fan or blower to induce a draft of air through the radiator of a water cooled engine or around the cylinders of an air cooled type.

Q. How are clutches attached to flywheels?

A. Cone clutches have the female members recessed in the flywheel interior, while multiple disc clutches or those of the expanding band type are housed in a drum or casing either machined with the flywheel casting or attached thereto by some method of mechanical fastening. Three and five plate clutches are carried on simple stud members screwed into the flywheel.

Q. How are flywheels attached to crankshafts?

A. Flywheels are attached to crankshafts either by means of a taper shaft and key retention or by means of bolting it when of the web type to a flange formed integral with the crankshaft. The latter is the preferred construction.

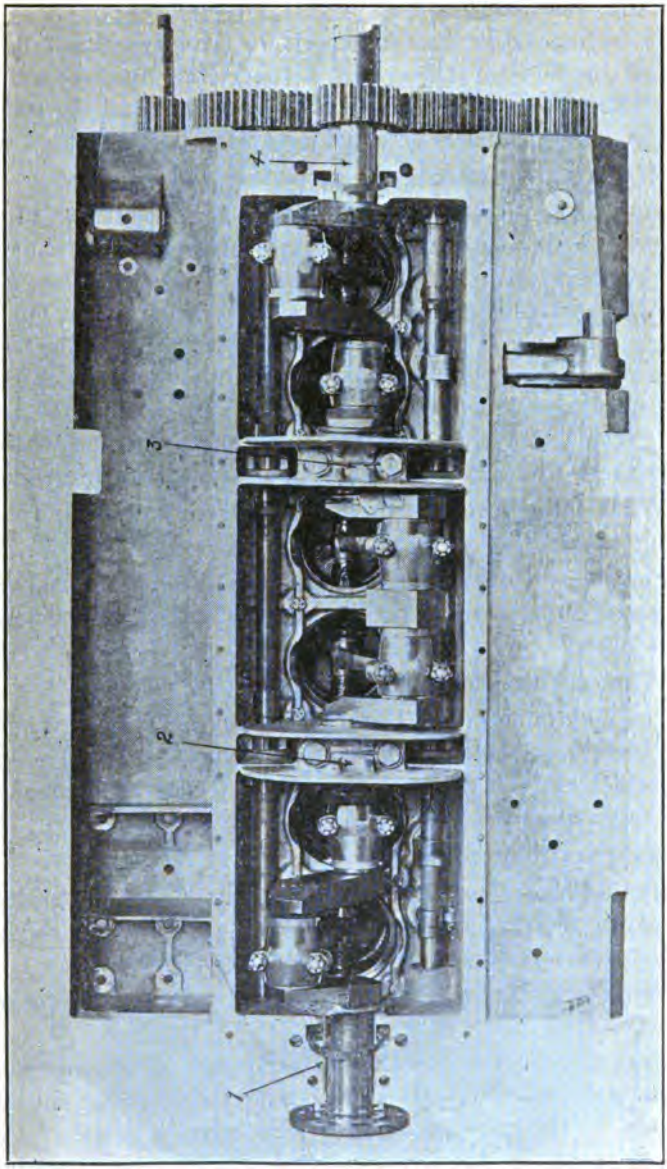


Fig. 56.—Bottom View of Engine Base of Six-Cylinder Motor, Showing Four-Bearing Crankshaft.

Q. Why must flywheels be securely fastened?

A. It is imperative that flywheels be attached firmly to the crankshaft, because any looseness between the flywheel and the shaft will produce a pronounced knocking sound, and the methods of fastening, such as keys or bolts, may be entirely sheared off.

Q. What is the meaning of marks on flywheel rims?

A. The marks placed on flywheel rims, as indicated at Fig. 39, are placed thereon to assist in timing the valves and ignition spark. The abbreviation E. O. means "Exhaust Opens," while E. C. means "Exhaust Closes." The letters I. O. mean "Inlet Opens," while I. C. means "Inlet Closed." The letter S. indicates the sparking point, while U. C. means "Upper Center," which means that the piston is at the top of its stroke, and L. C. means "Lower Center," which corresponds to the crank shaft position when the piston in the cylinder being timed is at the bottom of its stroke.

Q. What influence does flywheel diameter have on spacing of timing marks?

A. For a given number of degrees crank travel the marks are farther apart on large diameter flywheels than they are on those of lesser radius.

Q. What are the manifolds?

A. The manifolds are the built-up members or pipes that convey the fresh gas from the carbureting device to the valve chambers or which convey the inert products of combustion from the exhaust valve chambers to the muffling device.

Q. How are they secured to cylinders?

A. Manifolds are usually attached to cylinders by means of flange couplings bolted to the cylinders or by stirrups or retention bars which hold them securely in place.

Q. What precautions must be observed when designing manifolds?

A. Inlet or fresh gas manifolds should always be proportioned so that the gas from the carburetor does not have to turn any sharp corners and so the distance between each valve chamber of a multiple cylinder engine and the carburetor will be approximately the

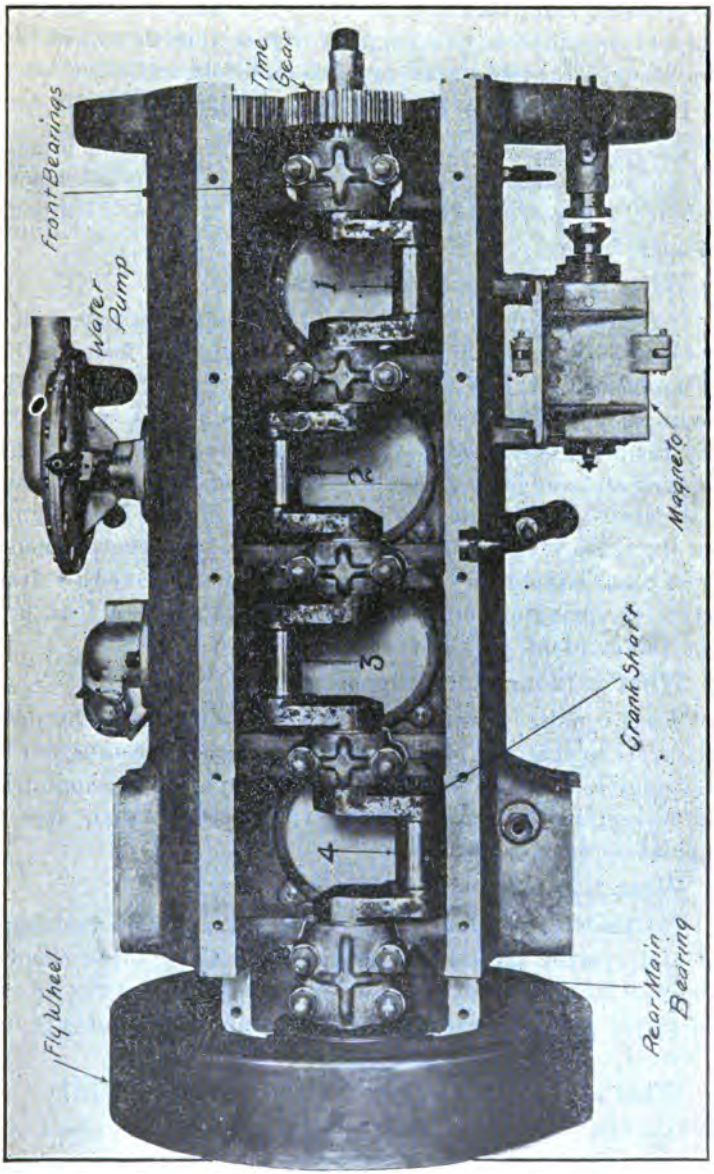


Fig. 57.—Bottom View of Four-Cylinder Motor Showing Five-Bearing Crank Shaft with Flywheel and Timing Gear Attached.

same. Exhaust manifolds should offer a free passage to the escaping gas and should be large enough in bore so that there will be no friction between the gas stream and the manifold wall.

Q. How is the engine base attached to vehicle frame?

A. The common method of construction is to cast arms integrally with the engine bed which extend to the main frame sides or rest on an inner frame or sub-frame member that is in turn supported by the main frame.

Q. What is the three point support"?

A. If the power plant is supported by three points placed in relation to each other so that the two on the same line form the base of a triangle while the third forms the apex, the engine is said to have a three point support. The advantages of this construction may be readily understood if one compares the action of a three legged stool and one having four legs on uneven ground. The stool with the three point support is not so much affected by irregularities in the surface on which it rests as is the four legged member. A power plant supported on three points is not affected by frame distortion or springing out of alinement as much as a four point support power plant.

Q. What is "four point support"?

A. When a power plant is held in place in the frame by means of four arms so that the point of support forms a rectangular figure, the engine is said to have four point support. The four point system necessitates the use of a more rigid frame than does the three point method of suspension.

Q. What is a unit power plant?

A. The unit power plant construction is that where the engine, clutch and gearset are attached together so these three members may be said to be supported by the same common carrier or case. A unit power plant with the three point support is commonly used in motor car construction.

Q. What are the advantages of the unit power plant?

A. One of the methods of installing the motor and gearset of an automobile is to attach these to a frame as separate members and

interpose some form of flexible coupling between the clutch shaft and the gear box to compensate for any disalinement of the two members due to frame distortion on rough roads. With a unit power plant, crankshaft, clutch and transmission shafts are held in the absolute alinement present when first assembled, and no amount of frame deflection can throw the three members out of the correctly alined position that insures maximum efficiency and minimum depreciation. (See Frontispiece.)

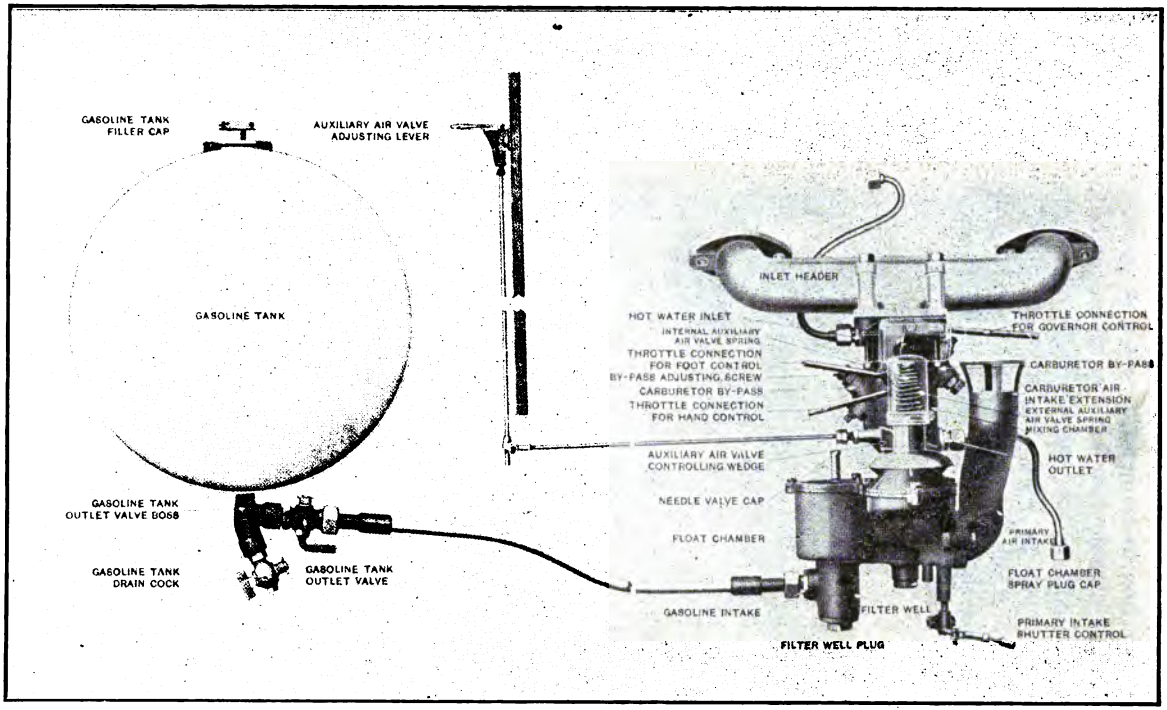


Fig. 58.—Outlining Arrangements of Parts of Typical Automobile Fuel Supply System.

LESSON FOUR

FUEL FOR AUTOMOBILE MOTORS

Q. What fuels can be used with the automobile power plant?

A. Internal combustion engines will operate satisfactorily on any form of hydrocarbon gas. This means that natural or artificial illuminating gas, alcohol vapor, acetylene, kerosene, benzol and gasoline vapors may be utilized.

Q. What are the disadvantages to the use of illuminating or natural gas as automobile fuel?

A. In order to carry enough gas for a tour or run of any consequence with an automobile it would be necessary to use very large storage tanks that would occupy considerable space that can be used to better advantages for other purposes. The same disadvantages that apply to the electric automobile regarding its operation at points remote from charging station would apply just as well to the gasoline vehicle if compressed gas was employed as fuel.

Q. What are the advantages of liquid fuel?

A. Liquid fuels have the important advantage that a relatively small supply can be carried in a container of small size compared to the total carrying capacity of the vehicle and that they may be readily handled and stored and easily secured at the present day at even the smallest village or hamlet.

Q. How are liquid fuels changed to gas?

A. A small amount of the liquid is sprayed into a charge of air and the mixture of air and liquid becomes a gas by the time the stream of vapor charged air reaches the cylinder interior. The gasifying process is accelerated by the heat of the motor.

Q. What is the general term applied to all liquid fuels?

A. The liquid fuels commonly used are generally designated as

hydrocarbons because the elements hydrogen and carbon are the chemical constituents of most liquids suitable for burning.

Q. Name the principal liquid fuels.

A. The principal liquid fuels mentioned in order of their importance are gasoline, naphtha, benzol, kerosene, and alcohol.

Q. Which is the best suited to modern engines?

A. The internal combustion engines used for vehicle propulsion have been designed with a view of using hem with readily evaporated liquids, such as gasoline.

Q. What is gasoline?

A. Gasoline is a highly volatile liquid that not many years ago was a by-product of but little value. It was used to a limited extent for removing oil stains from cloth or for cleansing delicate fabrics. It could be bought for four or five cents a gallon, and there was little market for it at that price until the gasoline stove was introduced. Engineers soon discovered that this substance evaporated very easily and mixed with air at ordinary temperatures to form a highly nflammable explosive gas.

Q. From what is gasoline derived?

A. Gasoline is one of the first products obtained by the distillation of crude petroleum. Petroleum is a dark, evil smelling liquid that comes from subterranean deposits and is obtained in large quantit es in several states, notably, Pennsylvania, Texas, Indiana, and Ohio. Crude petroleum is usually in association with natural gas. It is found in almost all parts of the world, but the largest proportion of that produced commercially is obtained from American wells. The petroleum found in this country yields more of the volatile products than those of foreign production. Many products and compounds are derived from crude oil, but before the crude product can be used it must be freed of the impurities such as free carbon, sulphur and various earthy elements which are in suspension in the liquid.

Q. What is the process of obtaining gasoline?

A. The process of purifying crude oil is one of destructive distillation and during this refining the various liquids of which the crude oil is composed are separated from each other and their com-

mon base. The oil is heated in large stills and the gases given off are condensed in a cooling coil and again turned to liquid. The oil is broken up into three main groups of products as follows: Highly volatile, which include naphtha, benzine, and gasoline; light oils, such as kerosene and light lubricating oils, and heavy oils or residuum.

Q. What proportion of the crude oil is gasoline?

A. The proportion of volatile products, such as gasoline, obtained from a given amount of crude oil varies from 6 to 10 % of the total. About 60% of the refined products is kerosene, 20% is light lubricating oil, while the remainder are various heavy oils and greases, such as vaseline, petroleum jelly and compounds of that nature.

Q. What are the properties of gasoline making it suitable as a fuel?

A. Gasoline evaporates readily at ordinary temperatures and can be mixed with air to form a satisfactory fuel gas by simple methods.

Q. Is gasoline dangerous?

A. Gasoline in itself is not dangerous unless enough of the vapor becomes mixed with air to form an inflammable gas. Owing to the volatile nature of this fluid, vapors are constantly given off whenever it is exposed to the action of the air, and because of this, the use of a naked flame or spark should always be avoided where gasoline is present in any quantity.

Q. What is kerosene?

A. Kerosene forms one of the most important of the distillates of crude petroleum and is the substance that is given off during the refining process following the evaporation of the more volatile gases that are condensed into the various grades of gasoline.

Q. Can it be used in engines of present design?

A. The chief difficulty which prevents the use of kerosene is that it will not vaporize readily at ordinary temperatures, and before it will evaporate sufficiently to form a gas, it must be heated. This calls for specially constructed vaporizing devices and water jacketed manifolds. Owing to the low rate of evaporation, kerosene cannot be used successfully on high speed motors where is it desired to have

flexible control and where the engine must be accelerated from a minimum to the highest speed in a short time.

Q. What are the advantages of kerosene?

A. At the present time kerosene is much more plentiful than gasoline, and when vaporized properly, it actually has more heat units and is capable of giving more power than does gasoline in equal quantities.

Q. Is kerosene dangerous?

A. Kerosene is not considered dangerous by the insurance companies, and large quantities of it can be stored without introducing the same element of fire risk that is present with gasoline. It is not constantly giving off vapors at ordinary temperatures, and will not burn unless it is spread in a thin film over some object where a large quantity will be exposed to the air. A burning match can be thrust into kerosene and the flame will be put out. The very condition that makes kerosene safer than gasoline, makes it less suitable as a fuel for present day forms of engines.

Q. Why is kerosene better for stationary power plants than for automobile engines?

A. Owing to the slow rate of vaporization, kerosene is more suitable for slow and moderate speed motors such as used for stationary and marine service than it is on high speed power plants.

Q. What is the relative value of kerosene and gasoline as fuels?

A. Kerosene actually contains more heat units per pound than gasoline does.

Q. What precautions are necessary to use kerosene?

A. When kerosene is to be used, it is necessary to provide some form of preheating coil through which the fuel is passed before it reaches the carburetor, to thoroughly heat the vaporizing chamber and induction manifold, and to proportion the mixture passages so the velocity of the entering gas will be high. It is necessary to provide an auxiliary device so the engine may be run on gasoline until it becomes warm enough to use the kerosene vapor. As kerosene contains more carbon in its composition than gasoline, and as the

combustion of kerosene vapor is not apt to be as complete as gasoline gas, with some forms of carburetor, a minute stream of water is sprayed into the mixture before it reaches the combustion chamber. The water is decomposed by the heat and liberates oxygen which facilitates combustion and which tends to minimize carbon deposit.

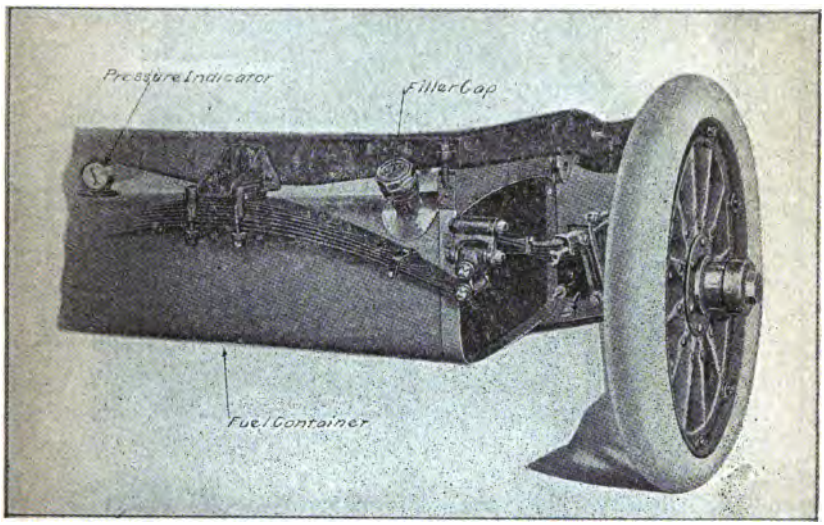


Fig. 58A.—Showing Method of Carrying Fuel Tank at Rear of Chassis on Lozier Cars.

Q. What is benzol?

A. Benzol is a by-product incidental to the manufacture of illuminating gas and coke. The crude product is a foul smelling liquid which has about the same color as ale, but when subjected to a refining process, the liquid is changed to one of about the same color of gasoline. Coke was formerly produced by a process of destructive distillation and the gases evolved were permitted to escape. At the present time these gases are retained and passed through a condensing coil to form benzol. About three gallons of benzol are obtained for each ton of coal converted into coke or gas.

Q. How is it used?

A. Benzol is not as volatile as gasoline but much more so than kerosene. A motor supplied with a carburetor of ordinary water or

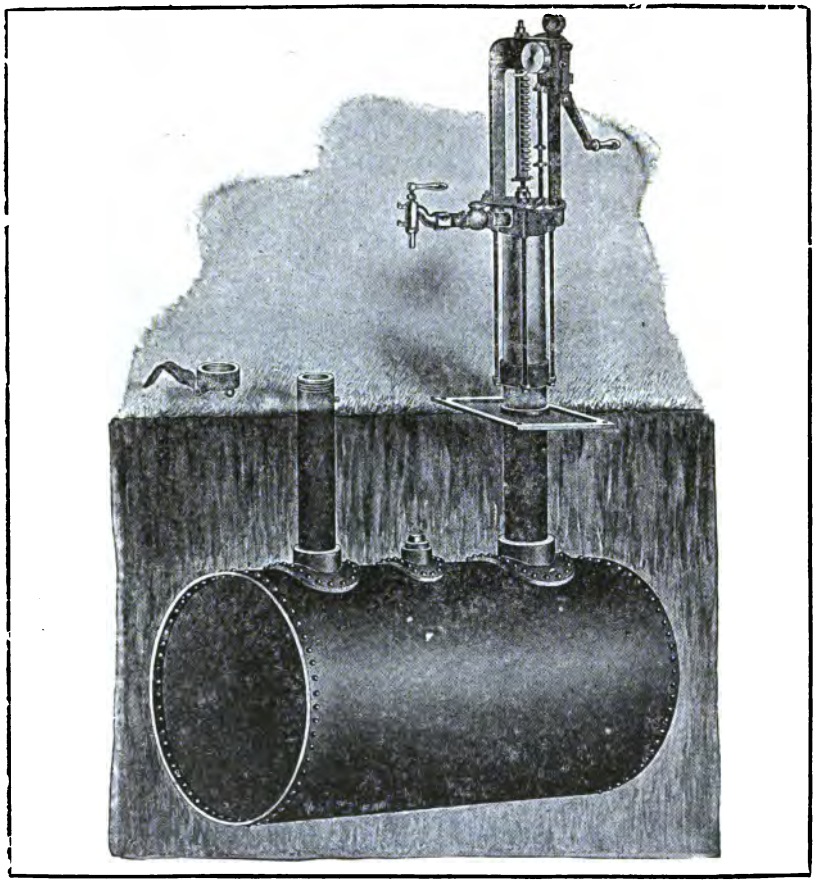


Fig. 59.—Showing Construction of Bowser Underground Gasoline Storage Tank With Attached Measuring Pump.

exhaust gas jacketed construction may be started without difficulty with this fuel. It has received considerable application in England.

Q. What is alcohol?

A. Alcohol is a product obtained from vegetable sources that offers some advantages as a fuel. It differs materially from gasoline, as it has from seven to ten per cent of water in its composition and as it is much less volatile it requires more heat to vaporize it.

Q. From what is it obtained?

A. Alcohol may be derived from any substance that contains either starch or sugar, and it can be produced from various fruits, grains and vegetables. Such materials as beets, potatoes, wheat, rye, corn, sugar-cane, barley, rice, and even decaying fruit or other refuse which could not be utilized otherwise may be distilled and alcohol derived therefrom.

Q. Can it be used as fuel?

A. While alcohol has been used for ten years or more abroad in engines designed especially for its use, it cannot be utilized economically in motors intended for gasoline. Alcohol vapor can be compressed much more than gasoline gas, and as the heat units liberated from a burning fuel vary with the amount of compression prior to ignition, even though alcohol gives out less heat when burned under the same conditions as gasoline, equal or higher engine efficiency may be obtained by compressing the alcohol vapor more. Alcohol is used in some form of carburetor adapted to heat the mixture before it is supplied to the cylinders. An engine designed for gasoline will use nearly twice as much alcohol as it does the other liquid to develop the same amount of energy. One of the disadvantages of alcohol that is shared in common with kerosene is that it is difficult to start a cold engine, and the motor must be heated up before alcohol can be used. Owing to the presence of oxygen in the alcohol, which is not a part of gasoline, only about one third as much air is needed with alcohol vapor and twice the amount of compression before ignition can be used with alcohol gas. It is claimed that the range of explosive mixture proportions of air and alcohol is much greater than that possible with gasoline and air.

Q. Describe the alcohol-acetylene process.

A. This is a recently devised process developed with the object of enabling one to use alcohol with engines of present design with no change except a special form of vaporizer. The alcohol vapor is passed through calcium carbide before it enters the cylinder and the water present in commercial alcohol, which normally lowers its efficiency as a fuel, is absorbed by the carbide and as a chemical action results, acetylene gas is liberated and this very inflammable gas

increases the thermal value of the alcohol vapor. When this combination gas is employed, it is necessary to add water to the alcohol to obtain the same thermal efficiency as procured with gasoline gas. The solution used as fuel contains 17 per cent water and 83 per cent alcohol; as water costs nothing to speak of, the increase in the bulk of fuel nearly pays for the carbide. It is estimated that one pound of carbide is used per gallon of liquid. This combination of alcohol and acetylene has proved efficient on motors employing compression as low as 60 pounds to the square inch and running as high as 2,000 revolutions per minute. If used alone, alcohol vapor burns

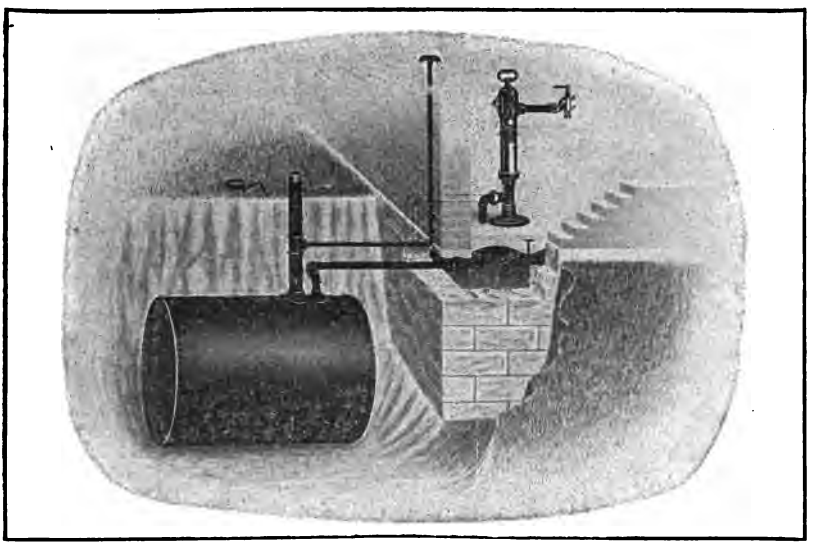


Fig. 60.—Bowser Gasoline Storage System Utilizing Underground Tank Outside of Building and Fuel Pump in Building.

slowly and it is more efficient on slow speed, high compression motors than on engines of the present form.

Q. What are the advantages of alcohol?

A. Alcohol has the great advantage that the fire risk is less than with gasoline. A gasoline fire or any burning petroleum product is only spread by water, but burning alcohol is extinguished by it. It is claimed that the exhaust gases from alcohol are cooler and cleaner

than those from gasoline vapor and they will deposit less carbon in the combustion chamber. As alcohol is obtained from vegetable substances there is no likelihood of fuel famine because the raw materials are not only found in all parts of the earth, but are reproduced each cycle of seasons and in fact, in tropical countries, there is no cessation to the growth of the vegetation. There has been no serious attempt to date to produce alcohol in large quantities and even the removal of the government tax on the denatured product has not stimulated the production of the liquid.

Q. Is alcohol dangerous?

A. Alcohol is much less dangerous than either kerosene, benzol or gasoline under ordinary conditions. Alcohol used for fuel purposes must be rendered unfit for drinking by substances such as benzine or other distillates of crude petroleum in order to make it unpalatable. As denatured alcohol is poisonous to a degree, it is very dangerous if the chauffeur takes it internally.

Q. How are fuels carried in automobiles?

A. Liquid fuels are carried in tanks conveniently disposed at various parts of the automobile, depending upon the type of fuel supply system used. In many cars it is carried in a tank under the front seat when a chassis is fitted with a touring body or in a large container back of the seat (Fig. 58) and at the rear end if the car is a roadster or two passenger type. On some very powerful machines where it would be difficult to store enough gasoline in a tank under the seat, a large container is carried at the rear end of frame back of the rear axle.

Q. What is the best system of fuel storage?

A. The safest method of handling gasoline and other liquids of like nature when stored in large quantities is to use underground tank outfits as outlined at Figs. 59 and 60. This is a very economical method, because the danger from fire is reduced to a minimum and there is no loss of fuel by evaporation. The liquid may be pumped up from the tank by any simple form of hand pump, some of which are so designed that they will pump only measured quantities of the l quid.

LESSON FIVE

THEORY OF CARBURETION AND ITS APPLICATION

Q. What is combustion a manifestation of?

A. Combustion always indicates a chemical combination between certain elements which have a great attraction or affinity for each other.

Q. Is combustion always rapid?

A. Combustion may be very slow as well as extremely fast.

Q. Give an example of slow combustion.

A. The rusting of metals or the rotting of wood, cloth and similar materials are examples of slow combustion.

Q. Give an example of rapid combustion.

A. Burning gas, wood, coal or oil are examples of rapid combustion.

Q. Give an example of instantaneous combustion.

A. The explosion of gunpowder or of the compressed gas in the automobile engine cylinder may be considered as practically instantaneous combustion.

Q. What is a vacuum and could anything burn in vacuo?

A. A vacuum is a space in which there is no air or other gas present. A vacuum may be nearly complete, but it is almost impossible to obtain a perfect vacuum. If a burning candle is placed under the receiver of an air pump and the air exhausted from the chamber in which the candle burns, it will be noticed that as the degree of exhaustion becomes greater, the flame burns dimmer until it finally goes out.

Q. What is necessary to support combustion?

A. Combustion cannot take place unless air or the element oxygen of which it is partly composed is present.

Q. What is gasoline composed of?

A. Gasoline is composed of carbon and hydrogen. The former is a solid material while the latter is the lightest known gas. When combined chemically, owing to the great affinity that exists between them, they will form a liquid if mixed in the correct proportions.

Q. How much of each element is there in gasoline?

A. The ordinary gasoline used for fuel is said to contain 84% carbon and 16% hydrogen.

Q. What is air composed of?

A. Air is composed of oxygen and nitrogen.

Q. Which element supports combustion?

A. The oxygen has a great affinity or combining power with the two constituents of the hydrocarbon liquids, and it is the oxygen which supports combustion. Nitrogen is an inert gas that is mixed with the air in order to act as a deterrent and prevent too rapid combustion.

Q. How much oxygen is needed to burn carbon?

A. One pound of carbon requires two and one third pounds of oxygen to insure its combustion.

Q. How much air is needed to burn a given weight of carbon?

A. As air is composed of one part of oxygen to three and one half portions of nitrogen by weight, for each pound of oxygen one needs four and one half pounds of air. It requires about ten pounds of air to burn one pound of carbon.

Q. Has air any weight?

A. While one does not consider air as having much weight, fourteen cubic feet of air at a temperature of 62 degrees F. will weigh about a pound.

Q. How much oxygen is needed to burn a given weight of hydrogen?

A. One pound of hydrogen requires 8 pounds of oxygen to burn it. This means that 6 pounds of air will be needed to insure combustion of the hydrogen component of gasoline.

Q. How much air is needed theoretically to insure the combustion of a pound of gasoline?

A. In order to secure combustion of one pound of gasoline one should provide about 16 pounds of air; 10 pounds of air is needed to burn the carbon contents and about 6 pounds to insure combustion of the hydrogen.

Q. How much air is actually supplied to burn a pound of gasoline?

A. Owing to the presence of the inert element nitrogen which is the main constituent of air and which acts as a deterrent of burning, it is necessary to provide more than the 200 cubic feet of air that theoretical combustion calls for and to allow about twice this amount. This means that about 32 pounds of air are supplied to burn one pound of gasoline.

Q. What is the liquid measure equivalent of a pound of gasoline?

A. Approximately 1.25 pints of 63 degree Baumé test gasoline will weigh a pound.

Q. What is carburetion?

A. In order to be explosive, gasoline vapor must be combined with definite quantities of air. Carburetion is the process of mixing the gasoline vapor and air in proper proportions to secure rapid combustion. Mixtures that are rich in gasoline ignite quicker than those which have more air, but these are only suitable when starting or when running the engine slowly, as they are very wasteful of fuel. Mixtures vary from 1 part of gasoline vapor to 4 of air, to others having but 1 part of gasoline vapor to 13 of air can be ignited, but the best results are obtained when the proportions are 1 to 5 or 1 to 7, as these mixtures will produce the highest temperatures, the most effective pressure in pounds per square inch of piston top area and the quickest explosion. What we commonly call an explosion is merely an indication that the oxygen of the air has combined with the carbon and hydrogen of the gasoline rapidly enough so that this chemical union is attended by heat. The power produced in the automobile engine cylinder is really due to a rapid chemical combination.

Q. Describe a number of ways in which liquid fuel may be mixed with air to form an inflammable vapor.

A. Almost any device which permits a current of air to pass over or through a volatile liquid will produce a gas that will explode when compressed and ignited in the motor cylinder. In some carbureting devices the entering air is made to pass over the surface of wicks saturated with liquid gasoline or the liquid fuels may be injected into the entering air stream in the form of a fine spray or mist. In other constructions the fuel is injected directly into the engine cylinder.

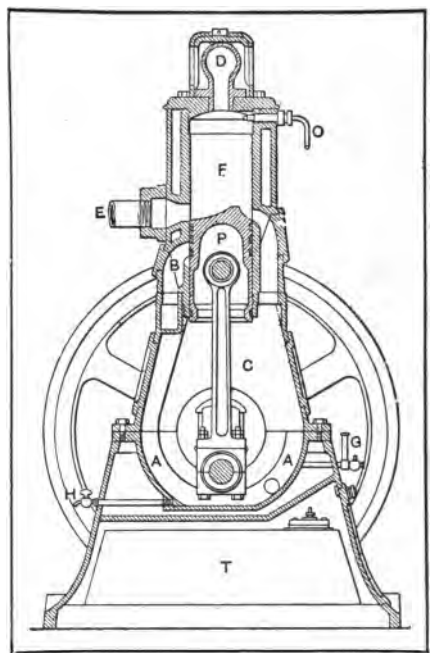


Fig. 61.—Section of Vertical Cylinder Fuel Injection Engine.

Q. What is the present accepted method?

A. The form of carbureting device widely used at the present time is known as the spraying type, because the fuel is drawn out of a stand pipe or jet in a fine stream which rapidly becomes a mist or vapor by the suction effect of the entering air stream. The advantage of this construction is that a thorough amalgamation of the gasoline and air particles is obtained. The primitive forms of vaporizers in which the air stream was passed over or through the high grade or very volatile gasoline that was first used for fuel, would be entirely unsuitable for use today. In the first place they would not carburete the lower grades of gasoline supplied at the present time, and secondly, they could not supply the modern high speed engine with gas of the proper consistency fast enough even if high grade fuel was available.

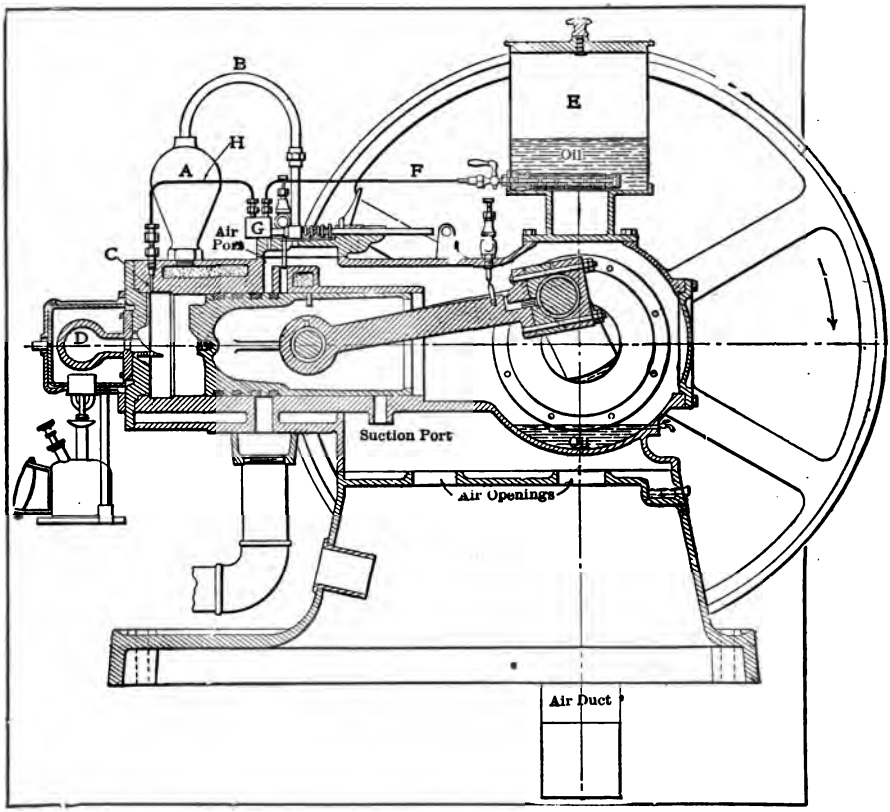


Fig. 62.—Sectional View of Horizontal Type Two-Stroke Stationary Fuel Injection Motor

Q. Describe the Diesel system.

A. A system of fuel supply developed by Dr. Diesel, a German chemist and engineer, is attracting considerable attention at the present time on account of the ability of the Diesel engine to burn low grade fuels such as crude petroleum. In this system, the engines are built so that very high compressions are used, and only pure air is taken into the cylinder on the induction stroke. This is compressed to a pressure of about 500 pounds per square inch, and sufficient heat is produced by this compression to explode a hydro-

carbon mixture. As the air which is compressed to this high point cannot burn, the fuel is introduced into the cylinder head under still higher compression than that of the compressed air, and as it is injected in a fine stream, it is immediately vaporized because of the heat. Just as soon as the compressed air becomes thoroughly saturated with the liquid fuel, it will explode on account of the degree of heat present in the combustion chamber. (Figs. 61, 62.)

Q. What are the advantages of the injection method?

A. The injection method of fuel supply has the important advantage of permitting the use of very cheap fuels which could not be utilized in ordinary forms of vaporizers on account of the high temperature needed to vaporize them.

Q. What are the disadvantages of injection engines?

A. Owing to the extremely high compression employed in injection engines, these must be made very substantial and strong, and this principle is suitable only for the comparatively slow acting power plants of the stationary or marine type. An injection engine is not as flexible as the electrically ignited carburetor supplied power plants used for automobile service, and this fact also militates against the injection principle for this use.

LESSON SIX

TYPES OF CARBURETORS AND THEIR ACTION

Q. What are the simplest forms of carburetors?

A. The old patterns of evaporation or surface carburetors were the simplest forms of carburetion devices and the modified device in which wicks were used was but slightly more complicated.

Q. Describe action of evaporation or surface type.

A. This form of carburetor consisted of a simple tank or container for the liquid and the air was drawn in and across the surface of the gasoline in order that it might become saturated with the vapors constantly present at that point. These rich gases were drawn into the engine through a simple form of mixing valve which permitted the entrance of an auxiliary supply of air from the outside of the container to dilute the rich gas and make it of a proper composition to insure energetic combustion.

Q. Describe action of wick type vaporizer.

A. The wick form of carburetor is essentially the same in construction as the simpler surface type except that the mixing compartment through which the air flows is separated from the fuel containing portion by means of a wall of absorbent material, such as wicks, which feed the gasoline up into the mixing compartment by capillary attraction and by spreading it over more surface make it easier for the air stream passing over the wicking to pick up gasoline vapor.

Q. Describe action of bubbling type carburetor.

A. The bubbling type differs from the other simple forms previously described in that the air enters at the bottom of the device and bubbles through the liquid to reach the mixing chamber from which it is drawn to the engine cylinder.

Q. Name objections to these forms.

A. Devices of the nature previously considered had great defects which would militate against their general adoption at the present day. They are only suitable for use in conjunction with high grade gasoline which has high evaporating value. It is doubtful if they would give satisfactory results with the low grade fuels available today. In many cases these devices were as large as the cylinder of the motor to which they were applied, and this factor would also be considered a disadvantage.

Q. What is the principle of spraying carburetor action?

A. The spraying form of carburetor was evolved to eliminate one of the great disadvantages present with the simple evaporation types. As these were used, the fuel contained therein became heavier, because only the lighter and more volatile constituents evaporated. After a motor had been running for some time, it was necessary to drain out the residue, and admit a supply of fresh fuel from the main container, because the heavy matter left after the more volatile vapors had passed into the engine could not be vaporized by an air stream merely brushing over its surface or passing through it. In the spraying type of carburetor the fuel is drawn into the entering air stream through a small jet or stand pipe which causes it to issue into the form of a spray which soon turns into vapor. With the spraying principle every particle of the fuel is used because the heavier portions are sprayed into the air stream at the same time that the lighter constituents are, and as the liquid enters the air stream in a finely divided state or as a mist it is almost immediately vaporized and turned into an explosive gas.

Q. Describe a simple mixing valve.

A. A simple form of mixing valve consists of a brass body portion having three outlets. The largest of these, which serves as the main air entrance, is normally closed by a mushroom valve which is held against its seat by means of a coiled spring in such a way that it can only open when acted on by the suction of the engine. The fuel is connected to the device at a point where a small passage leads from the fuel inlet to the poppet valve seat. Whenever the valve is closed, the fuel spray opening is covered by the valve and

the fuel cannot flow. The third opening forms an outlet for the mixture and is connected to the engine. The action of a device of this kind is easily understood. Every time the piston of the engine draws in a charge of air, it lifts the mushroom valve from its seat and a small quantity of liquid fuel is injected into the air stream as it brushes over the small orifice in the valve seat through which the liquid issues. The liquid spray and air become mixed together in the body of the device and flow to the engine in the form of an explosive mixture.

Q. How are mixture proportions regulated?

A. As a general rule the amount of gasoline supplied may be regulated by a small needle valve controlled by a knurled thumb nut while the air supply may be altered by controlling the lift of the air valve by suitable means.

Q. Name defects of simple mixing valves.

A. One of the most important disadvantages of the simple mixing valve is that it does not provide as good a mixture as modern high speed engines demand, because it does not vaporize all of the liquid, and some of the fuel is present in liquid form until taken into the hot cylinder. At low engine speeds particles of liquid fuel will adhere to the walls of the manifold and when the engine speed is augmented and the velocity of the gases passing through the manifold increases, the air stream picks up some of the liquid previously deposited in the inlet pipe and the result is a mixture excessively rich in fuel is supplied the motor. Another disadvantage is that after the device has been in use for a time the air valve might wear its seat enough so that it does not prevent the gasoline from running out all the time and flooding the air inlet opening with the liquid.

Q. What is a float feed carburetor?

A. A float feed carburetor is a device in which the fuel is maintained at a certain level in a stand pipe or jet. This level is so proportioned that the liquid does not overflow the stand pipe, and thus the fuel will be sprayed into the mixture only when drawn out of the jet or nozzle by means of the air stream induced by engine suction. The level in the spray nozzle is maintained by a simple automatic valve mechanism in which a float controls the admission of

fuel to the device. The essential elements of a simple form of float feed carburetor are clearly outlined at Fig. 63.

Q. Name two important parts of the float feed carburetor.

A. All float feed carburetors are composed of two separate chambers or compartments, one of which is called the mixing chamber and the other the float chamber.

Q. What is the mixing chamber?

A. The mixing chamber is the portion of the carburetor in which the spray nozzle is placed and through which the air stream passes before it can reach the inlet manifold.

Q. What is the float chamber?

A. The float chamber is that part of the carburetor to which the fuel is first admitted and which serves as a container for the float which regulates the level of fuel in the standpipe. Whenever the fuel level falls, the float which is supported by the liquid falls and opens a valve which permits more of the liquid to flow into the float bowl from the main fuel container. When the level reaches the proper height the float shuts the valve and the fuel supply is stopped.

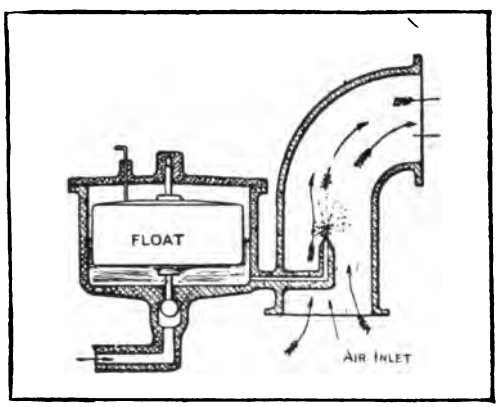


Fig. 63.—Defining Elements of Simple Float Feed Carburetor.

Q. What are floats made of?

A. The float may be solid and composed of some light substance that will float in the liquid or it may be of hollow metal of any form that will displace more than its weight of fuel. Cork is the material generally used for solid floats, while sheet copper or brass serves for the hollow members.

Q. How many methods of mixing chamber placing relative to float chamber prevail?

A. There are two common arrangements of the float and mixing chambers as outlined at Fig. 64. In one, the float chamber is carried at one side of the mixing compartment, while in the other the float chamber is concentric with and surrounds the mixing chamber.

Q. What are the advantages of the concentric design?

A. When a float bowl is carried at the side of the mixing chamber the level in the jet will vary except when the device is absolutely

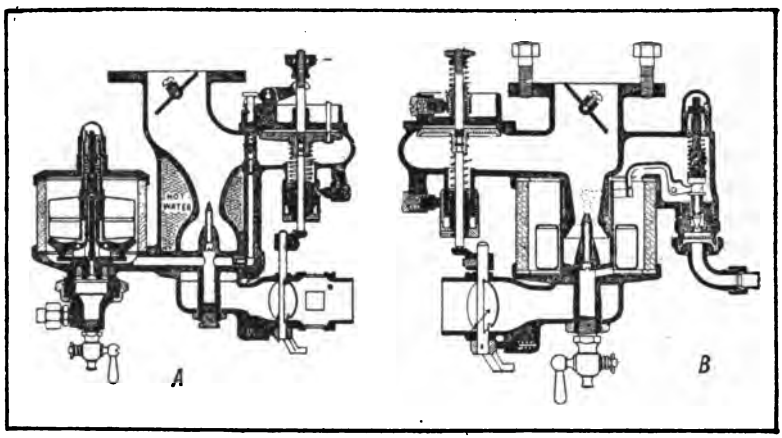


Fig. 64.—Showing Conventional Methods of Float Chamber Placing. A—At Side. B—Concentric With Mixing Chamber.

level. If the float chamber is in front of the mixing chamber when climbing a grade, it will tend to cause flooding, because it is tilted higher than the spraying nozzle top. When descending a hill the conditions are reversed and the fuel level in the spray nozzle will be too low and not enough liquid will be sprayed into the mixture. With the concentric design, where the spray nozzle is carried at a central point of the carburetor, no reasonable amount of tilting will alter the level of liquid at that point appreciably. The concentric construction is preferred because it tends to promote uniformity of mixture proportions under all conditions of car operation.

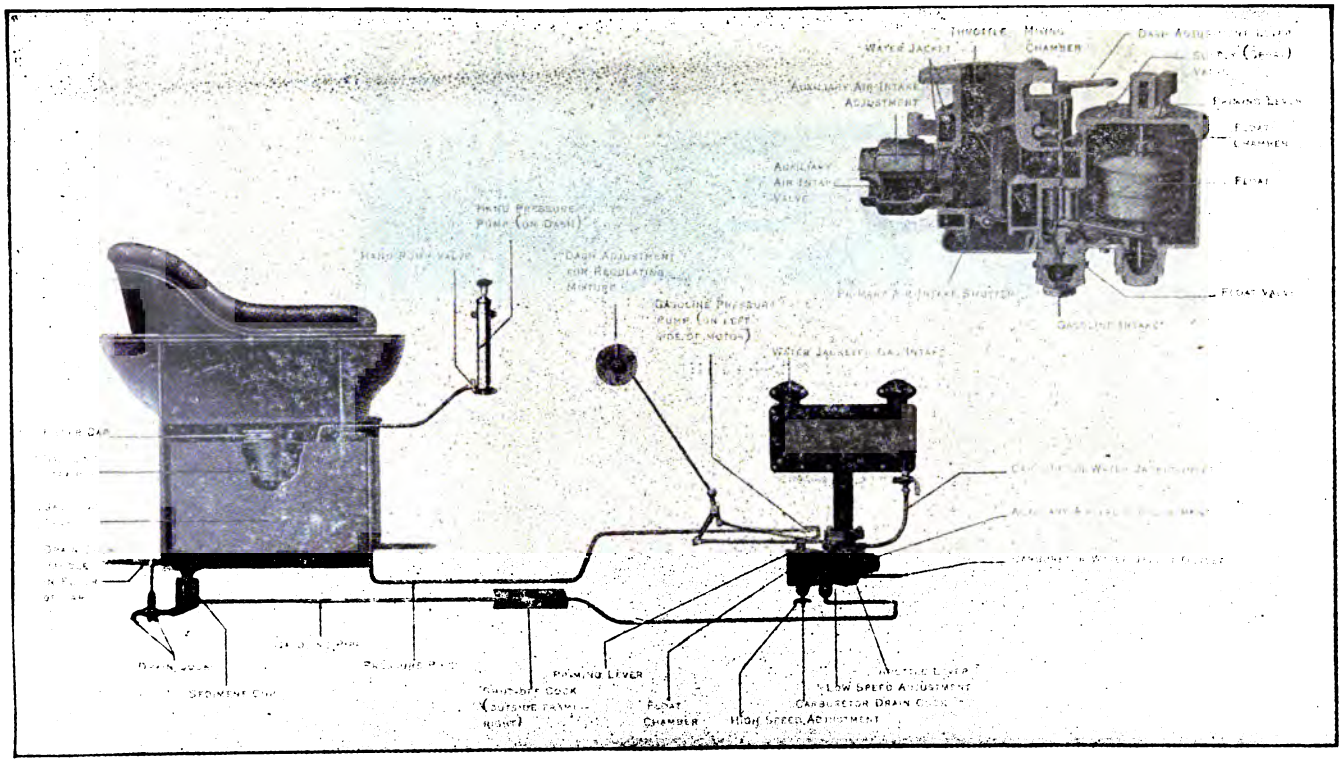


Fig. 65.—Complete Fuel Supply System of Chalmers Car, Showing Gasoline Tank Under the Seat and Piping Leading to Carburetor. Sectional View of Carburetor Outlined in Upper Right-Hand Corner.

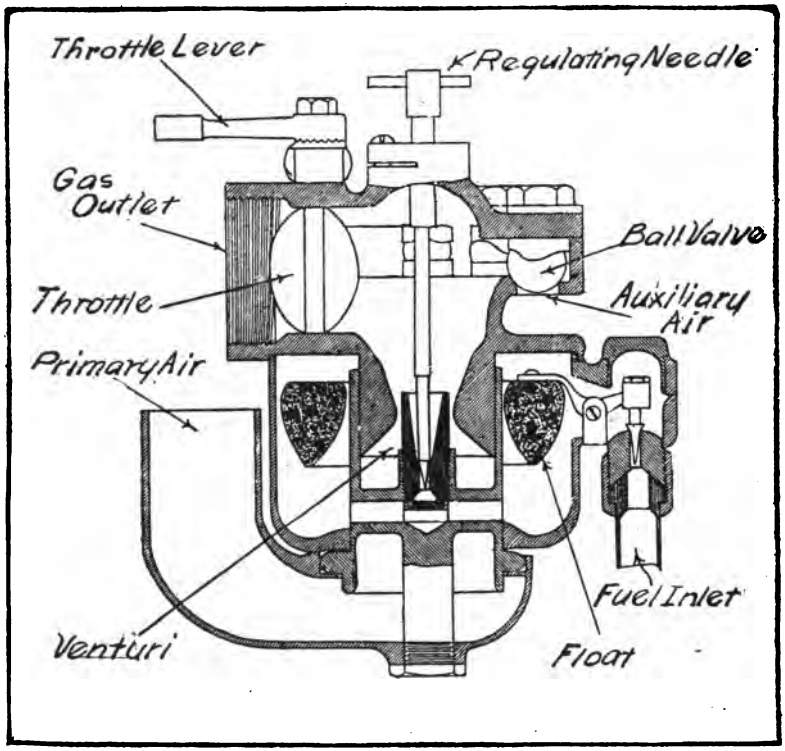


Fig. 66.—Sectional View of Kingston Carburetor, Which Uses Venturi Type Concentric Mixing Chamber.

Q. What is the Venturi tube mixing chamber?

A. A Venturi tube mixing chamber of conventional design is clearly outlined at Fig. 66. In this it will be noticed that the mixing chamber is constricted at a point approximately in line with the top of the jet. This insures a high velocity of air past the top of the spray nozzle even at low engine speed. With a straight mixing chamber the speed of the entering air stream at low engine speed might not be sufficient to pick up enough fuel to form an explosive mixture. Constricting the tube at the proper point means that the air velocity will always be sufficient to draw a full supply of liquid from the spray nozzle.

Q. What is an automatic carburetor and why is it needed?

A. Whenever a Venturi tube construction is employed to secure greater air velocity at low speed it is apparent that at high engine speed the air velocity might be great enough to draw more fuel than was actually needed into the engine cylinder. This would mean that the excessively rich mixture provided at high engine speed would cause overheating and waste fuel and a comparatively thin mixture at low engine speed would interfere with prompt starting. In actual practice these conditions should be reversed. The rich mixture is only necessary for starting while a much

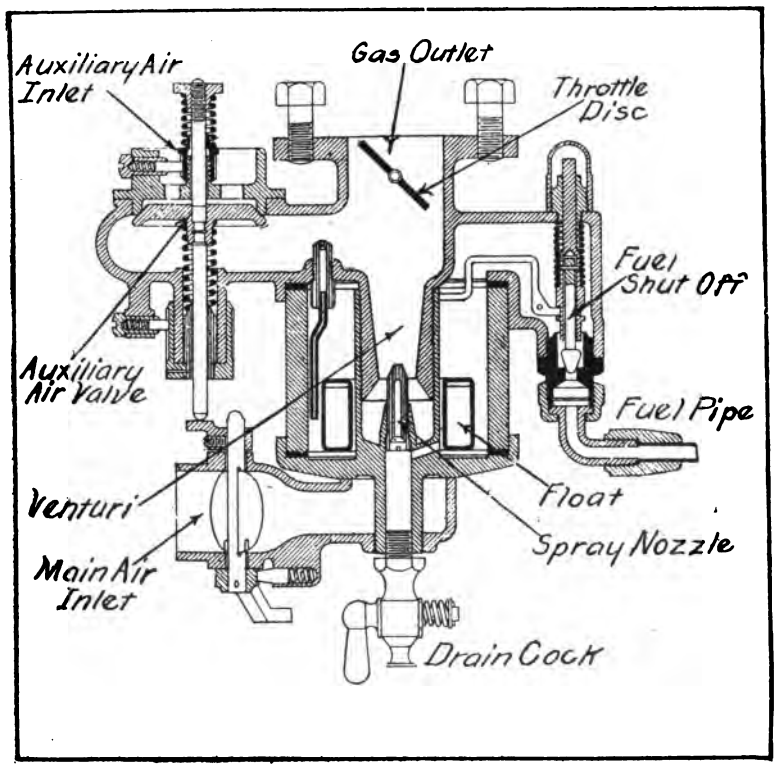


Fig. 67.—Typical Concentric Float Carburetor With Poppet Valve Controlling Auxiliary Air Supply.

thinner mixture or one containing a larger proportion of air can be used to advantage at high engine speed. The automatic form of carburetor, which is the type generally used to-day, provides for the introduction of an auxiliary supply of air through a separate opening that will dilute the excessively rich mixture obtained at higher speed and make it more suitable as a combustible gas.

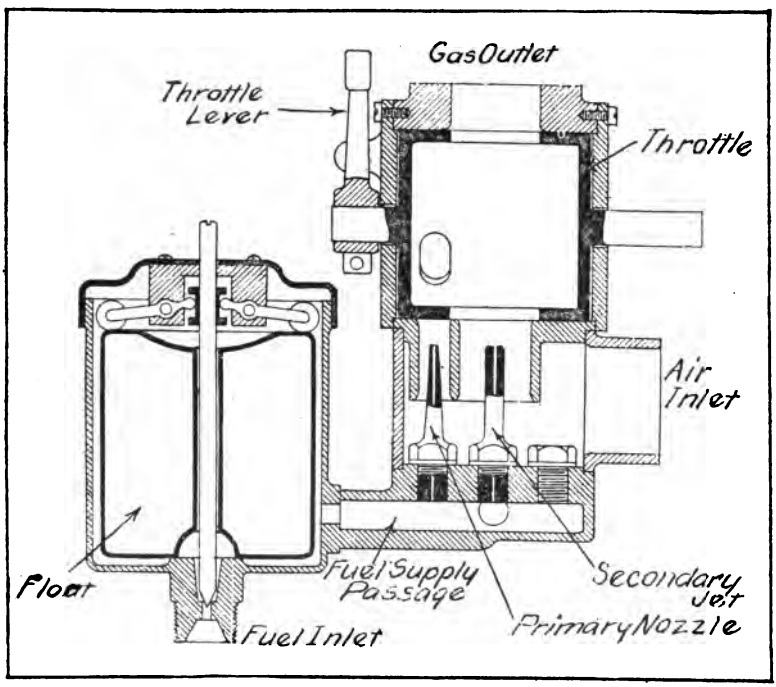


Fig. 68.—Two Jet Carburetor of Simple Design.

Q. How may auxiliary air be admitted to the carburetor?

A. The auxiliary air passage may be controlled by any form of automatic valve. In the design shown in Fig. 67, the air is admitted by means of an ordinary spring seated mushroom or poppet valve. The spring tension is so proportioned that the valve will open only on medium and high engine speeds, at which times the suction is

greater than that prevailing at low speed. The auxiliary air passages are sometimes controlled by means of reeds which open progressively as more auxiliary air is needed or by a series of balls which close the auxiliary air ports. The strength of the reeds or the weight of the balls may be varied so the air passages will open progressively and admit more air as the demands increase.

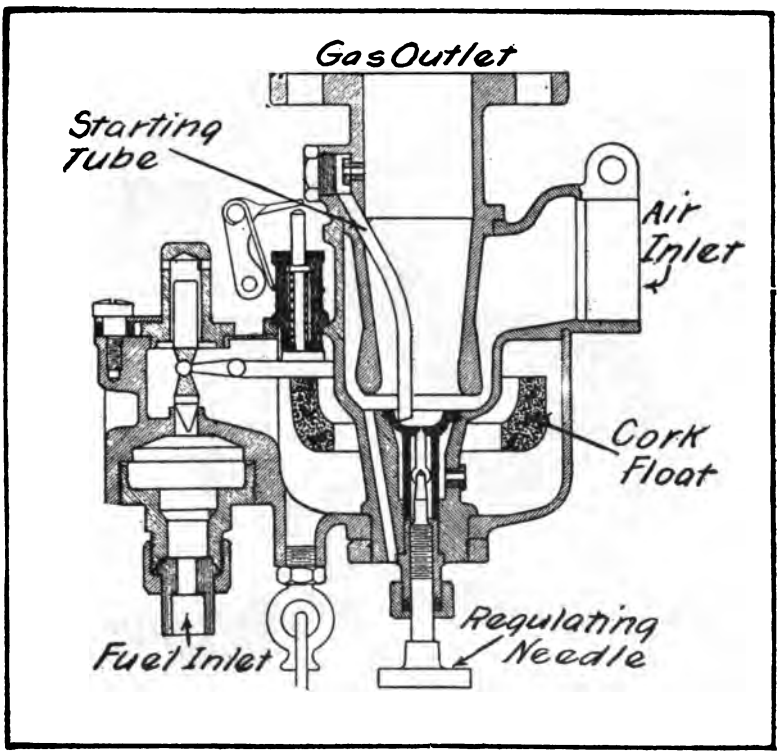


Fig. 69.—Latest Holley Carburetor Has Fixed Air Intake and No Auxiliary Air Valve.

Q. What is a multiple jet carburetor?

A. A simple form of multiple jet carburetor is shown at Fig. 68. In a device of this character, two or more spray nozzles are used instead of a single jet. The arrangement is usually such that the

primary nozzle is used at low speed while the secondary nozzle is brought in action at higher speed when more fuel is needed. In some types the arrangement is such that the primary nozzle acts only at low speed while the secondary nozzle supplies gasoline only at high speed. In other multiple jet carburetors, the nozzles are brought into action progressively when the throttle is opened to

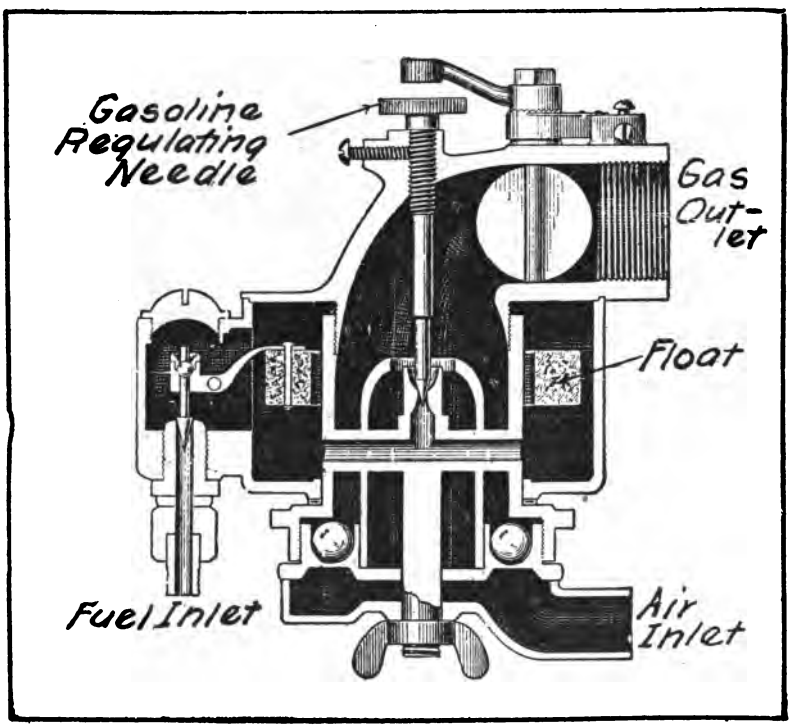


Fig. 70.—Sectional View of Planhard Carburetor Showing Fuel Supply Regulating Needle.

such a point that the primary nozzle, which has a small spraying orifice, cannot supply fuel enough; then the secondary nozzle is brought into action and contributes its quota of liquid to compensate for the augmenting demand of the engine.

Q. How is the simple type of carburetor adjusted?

A. In the simplest forms of carburetors, the amount of gasoline or other fuel supplied the mixture can be altered only by changing spray nozzles until one having the proper size hole to suit the conditions then prevailing is found. On some types, a slight degree of adjustment is provided by altering the float level, while in others the main or auxiliary air supply is varied.

Q. How are gasoline proportions usually regulated?

A. In most of the carburetors that have received general application, such as the types outlined at Figs. 69 and 70, the spray nozzle orifice is controlled by a needle valve which may be used to regulate the amount of gasoline entering the air stream.

Q. How is the amount of air varied?

A. In some forms of carburetors no provision is made for altering the amount of air supplied the mixture. This is usually the case in those forms where the auxiliary air supply ports are controlled by a series of reeds or balls. In the types where one valve regulates the auxiliary air supply, the amount of air may be varied by increasing or decreasing the spring tension or by regulating the lift of the valve.

Q. How can one tell when the mixture is not correct?

A. There are two methods of determining poor mixture. If the engine action is irregular and the trouble is not due to ignition, or to defective motor parts, it can be ascribed to faulty carburetion. The exhaust gas also indicates if the mixture is too rich.

Q. How can one tell when there is too much gasoline in mixture by motor action?

A. An excess of fuel in the mixture will tend to make the motor overheat and be sluggish in action.

Q. What indicates an excess of gasoline in the mixture at the exhaust?

A. Clouds of black smoke issuing from the muffler or a foul smelling exhaust indicates that too much gasoline is present in the mixture. When there is an excess of liquid fuel and combustion is poor, the exhaust gases in addition to smelling very strong, will

have a tendency to affect the eyes of a person standing in the path of the discharging gas.

Q. What do clouds of white or gray smoke at the muffler indicate?

A. White or bluish white smoke means that too much lubricating oil is being used, while gray smoke indicates that in addition to a surplus of lubricating oil, there is too much gasoline in the mixture.

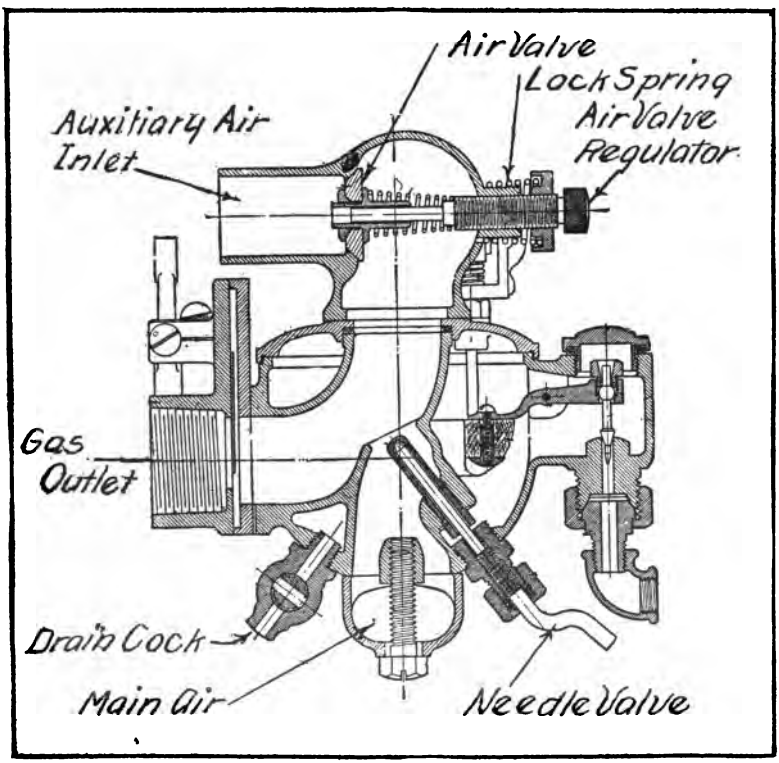


Fig. 71.—Sectional View of Schebler Model E Carburetor Showing Auxiliary Air and Spray Nozzle Regulation.

Q. What shows an excess of air in the mixture?

A. The most common symptom denoting an excess of air is pop-

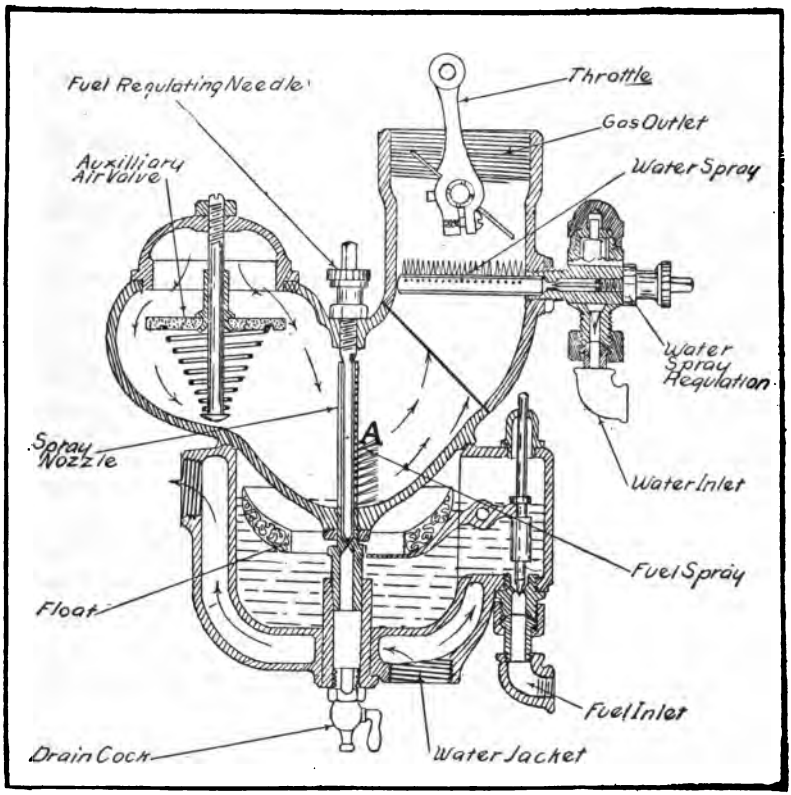


Fig. 72.—Outlining Method of Utilizing Water Spray in Kerosene Vaporizer to Facilitate Combustion.

ping back in the carburetor, and loss of engine power even if there are no popping sounds.

Q. When are the exhaust gases visible?

A. The exhaust gas as it issues from the end of the manifold or through the muffler cut-out fitting is clearly visible after dark.

Q. What color is the exhaust gas when mixture is correct?

A. If combustion is good the exhaust gas will be almost colorless and have the bluish tinge that is present in the flame of a gas burner of the Bunsen type or blue flame oil burner.

Q. What color is the exhaust flame when there is too much gasoline?

A. If the exhaust gases are reddish in color, it indicates a surplus of fuel.

Q. What color is the exhaust when there is too much air in the mixture?

A. The exhaust flame is yellow in color when there is an insufficient amount of gasoline in the mixture.

Q. What is the advantage of water-jacketing a carburetor?

A. It is very desirable to water jacket the float bowl of the carburetor and the mixing chamber and to pass some of the cooling water from the cylinders through this jacket. The heat assists in vaporizing the liquid and makes more uniform mixture proportions.

Q. Why is it desirable to supply hot air to a mixture?

A. In many cases the main air supply is taken from a point near the exhaust manifold so that only heated air is drawn into the carburetor. The advantage of using heated air is that it is more suitable for use with low grade fuels which do not evaporate readily than cold air. The warm air tends to vaporize the liquid, whereas cold air tends to condense the vapor.

Q. How are low grade fuels utilized with conventional vaporizers?

A. There are two methods of using carburetors of the design adapted for gasoline with the lower grade fuels such as kerosene. These are outlined at Figs. 72 and 73. In the former, in addition to pre-heating the fuel by a water jacket around the float bowl, a spray of water is injected into each gas charge. The function of the liquid is to turn into steam from the heat of the explosion, liberating oxygen which combines with the surplus carbon and tends to make combustion more perfect.

At Fig. 73, a carburetor intended for use with either kerosene or gasoline is shown. The supply pipes from both gasoline and kerosene tanks are led to a common fitting or valve which can be turned so that either liquid will be supplied the float chamber. When gasoline is used, the mixture flows directly to the cylinder because the supplementary throttle is moved in such a position that the

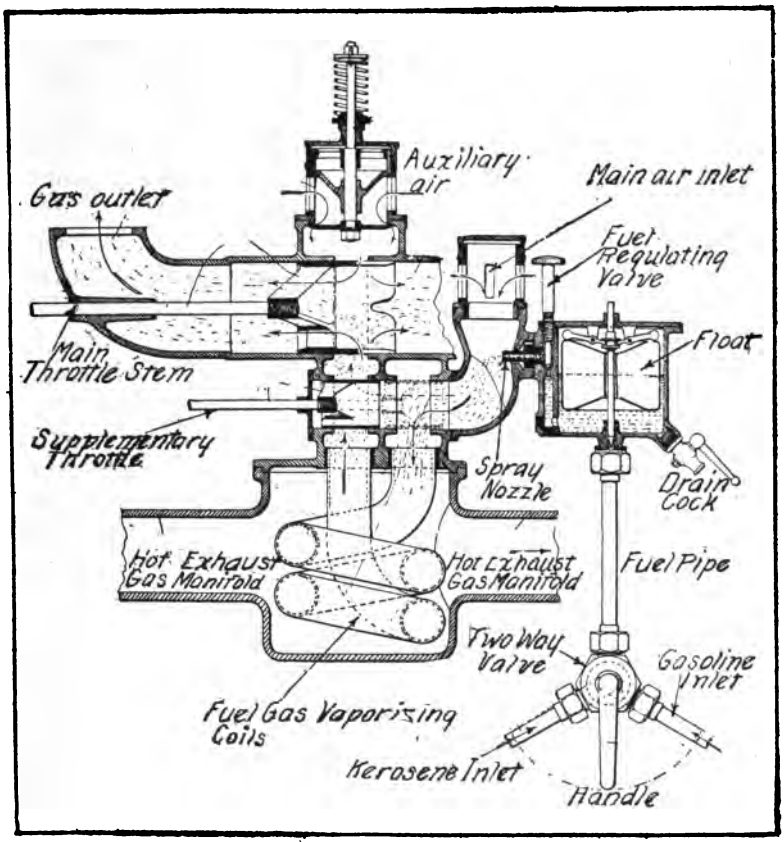


Fig. 73.—Sectional View of Woolsely Two-Fuel Carburetor Which is Adapted to Vaporize Either Gasoline or Less Volatile Fuels Such as Kerosene.

mixture is not forced through the fuel gas vaporizing coil, but passes right into the cylinder through the main throttle and gas outlet. When kerosene is employed, however, it is necessary to heat the vapor to insure thorough vaporization. The supplementary throttle is then moved out in such a way that the fuel gas must pass through the vaporizing coils which are surrounded by the hot exhaust gases before they are drawn into the cylinders.

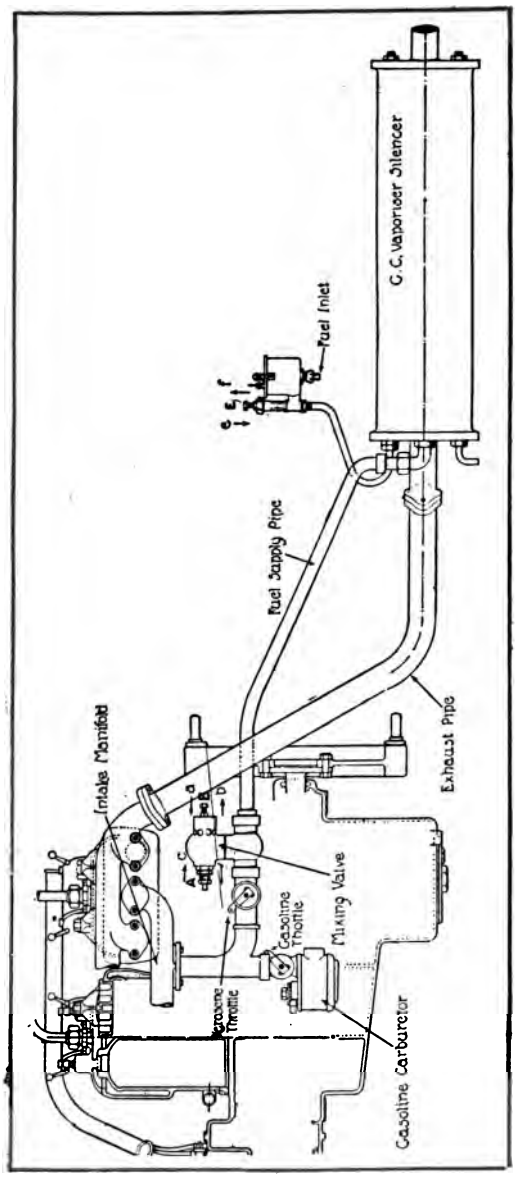


Fig. 73a.—Diagram Showing Method of Connecting the G. C. Kerosene Vaporizer to Conventional Four-Cylinder Automobile Engine Without Interfering With Operation of the Power Plant on Gasoline if Desired.

Q. Describe the G. C. kerosene vaporizer, and explain its action.

A. The general arrangement of parts of G. C. kersoene vaporizer is illustrated at Fig. 73-a. This device has been in use in England for nearly two years and has been applied with success on commercial vehicles, motor boats and stationary engines. An advantage is that this type of kerosene vaporizer does not interfere in any way with the design or construction of the motor which retains the usual gasoline carburetor. This is employed for starting purposes, and the engine is run on gasoline until sufficient heat is obtained to va-

porize the heavy fuel. The desired temperature for vaporizing the kerosene may be attained after motor operates five or six minutes. As the heavy fuel mixture is conveyed to the intake manifold above the regular form of carburetor, it is possible to use either fuel independently and run the motor on one fuel should the supply of the other become exhausted.

The G. C. vaporizer replaces the conventional muffler, and the exhaust gases are led to it from the motor, so the heat usually wasted is utilized for aiding in vaporizing the heavy fuels. The exhaust gases pass through the central portion of the vaporizer and during their passage they heat up a triple layer of small fragments of cast iron through which a horizontal pipe extends containing the fuel to be vaporized. Atmospheric air is drawn through the vaporizer at the same time from another opening, and as this mixes with the kerosene vapor, the cylinders are fed with a homogeneous gas. The amount of kerosene entering the vaporizer is automatically regulated by the motor suction and the supply increases in proportion to the motor speed because the degree of vacuum in the cylinders depends on the amount of throttle opening. The kerosene supply pipe goes to a float chamber communicating with the vaporizer by an independent p pe. The mixture from the vaporizer goes to the intake manifold, through a long fuel supply pipe, the motor end of which is fitted with an auxiliary air mixing valve and a throttle for regulating the amount of gas going to the cylinder.

The adjustments are very simple, and once the vaporizer is installed it is claimed that it requires no further attention. If the motor shows evidence of smoking, the adjustment *A* of the auxiliary air valve is moved in the direction of the arrow *D*. If the engine back-fires because the mixture is too thin, the adjusting screw *A* is screwed in the direction of *C*. The low speed adjustment is obtained by the screw *B*, which is moved in the direction *a* if the motor smokes and toward *b* for back-firing. The amount of kerosene entering the vaporizer-silencer may be regulated by moving the screw *E* on the float chamber in the direction *e* for smoking, and in direction *f* if the motor back-fires.

It is claimed that this device permits the use of other fuels besides kerosene, as it has operated successfully on alcohol, heavy petro-

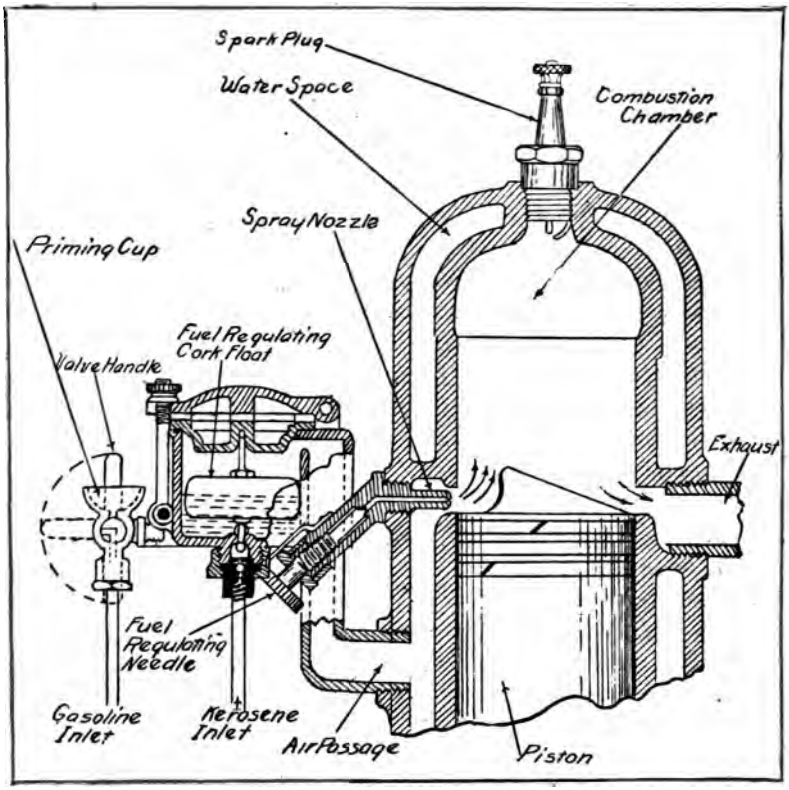


Fig. 74.—Defining Method of Utilizing Kerosene in Two-Cycle Motors by Direct Injection in Cylinder.

leum, and very low grade kerosene, commonly called "distillate." When properly adjusted, it is advanced that the consumption of kerosene is about 20% less than gasoline needed for the same power output. To start a motor employing this system it is necessary to close the kerosene throttle entirely and to start the motor on the gasoline carburetor and regulate its speed for five to ten minutes by the gasoline throttle at the lower portion of the intake manifold. When it is desired to operate on kerosene, the gasoline throttle is gradually closed and the kerosene gas controlling throttle is gradually opened until the motor is running on the kerosene mixture.

Q. What else may be done to use kerosene?

A. Some forms of two-cycle motors use kerosene by the method outlined at Fig. 74. When the air is transferred from the engine base where it has been compressed, a portion of the air stream is deflected through a by-pass to the top of the float bowl so that the liquid contained therein is placed under pressure. This pressure causes a certain amount of the fuel to spray through the spray pipe or nozzle placed at the top of the cylinder by-pass passage and a stream of kerosene is injected into the entering air stream and vaporized. With either of these systems it is not possible to start directly on kerosene; it is necessary to run the engine on gasoline until it becomes hot enough to evaporate the less volatile liquid fuel. With the carburetor shown at Fig. 73, it is a relatively simple matter to change from one fuel to the other. With the injection system shown at Fig. 74, the float bowl may be filled with gasoline directly from the gasoline tank with the valve handle in the position shown by the dotted line, and when the valve handle is straight up the gasoline inlet is shut off and the fuel supply is through the kerosene inlet.

Q. What becomes of the burnt gases when they are discharged from the engine?

A. After the burnt gases pass out of the cylinder, they pass through the exhaust manifold and exhaust pipe to the muffler.

Q. What is a muffler?

A. A muffler is a simple device designed to silence the gases as they issue from the engine before they pass to the outer air with as little loss of power due to back pressure as possible.

Q. Why is it imperative that as little back pressure exist in muffler and exhaust piping as possible?

A. When the gases are discharged through the open exhaust valve, their pressure is approximately 40 pounds per square inch, and if the muffler and exhaust piping offers a decided resistance to their passage to the outer air, there will be a negative pressure equivalent to that exerted by the exhaust gases that will tend to prevent the piston coming to the top of its scavenging stroke. This would mean that considerable force or power would be utilized in

expelling the exhaust gases that could be employed to much better advantage in propelling the car.

Q. What is a muffler cut-out valve?

A. The muffler cut-out valve is a fitting interposed between the exhaust manifold and the muffler in such a way that it can be operated to allow the exhaust gases to escape directly to the air from the manifold without passing through the muffler.

Q. How is a muffler cut-out valve operated and what advantage does it offer?

A. The muffler cut-out valve is usually operated by a simple pedal that can be pressed down by the toe or heel of the foot and locked in the open position. A muffler cut-out offers several advantages, the most important being that it permits the motorist to listen to the explosions to see that they follow in regular sequence and also to relieve any back pressure due to the muffler when all the engine power is needed as in high speed work and hill climbing.

Q. Can a muffler be both silent and efficient?

A. Mufflers of modern construction offer but little back pressure and are silent enough so that nothing but a barely perceptible hissing noise is heard when the engine is running.

Q. Describe method of silencing the exhaust in a muffler.

A. A muffler consists of a series of compartments in which the gases are allowed to expand and as they increase in volume their pressure is reduced. The exhaust passes from one compartment of the muffler to the neighboring one through a series of holes which break up the main stream into a number of smaller streams, this cooling the gases and reducing the pressure until it is but slightly greater than that of the air. The ideal muffler would be one that would discharge the gases only when their pressure had been reduced to such a low point that there would only be difference enough between the exhaust gas and atmospheric pressure to insure clearing out the muffler.

LESSON SEVEN

HOW GAS IS EXPLODED IN CYLINDER TO PRODUCE POWER

Q. How can explosive gas in cylinder be exploded?

A. The compressed gas in the motor cylinder may be exploded by setting fire to it by the application of heat.

Q. When is the charge fired?

A. The charge is exploded when the piston reaches the end of its compression stroke or at top position and just prior to the inception of the power stroke..

Q. Name some early methods of exploding the gas.

A. The gas charge was exploded on early, slow speed, low compression motors by means of a naked flame, hot tube or hot head.

Q. Describe objections to open flame method.

A. The open flame method was suitable only for use on the very early engines that did not compress the charge before ignition. The flame burned outside of the combustion chamber, and at the proper time for firing the charge, a small slide or valve permitted the flame to communicate with the contents of the combustion chamber and explode them. The chief objections were uncertainty of ignition, as many explosions were missed, blowing out of the flame and difficulty of using the flame with even small degrees of compression.

Q. Outline hot tube method.

A. The hot tube was an improvement on the naked flame, and consisted of a simple porcelain or metal tube which was heated by a flame burning outside of the cylinders. Two types of hot tubes are indicated at Fig. 75, while the method of installation can be readily ascertained by examining the diagram at Fig. 75-A. As the gas was exploded by means of the heat of the tube and the naked flame did not communicate directly with the interior of the combustion

chamber, the objections advanced against the simpler open flame ignition were eliminated to a degree.

Q. Where is this method still used?

A. The hot tube method of ignition is still utilized in some forms of stationary engines using crude oil as fuel.

Q. What is the hot head method of ignition?

A. The hot head method of ignition which is outlined at *B*,

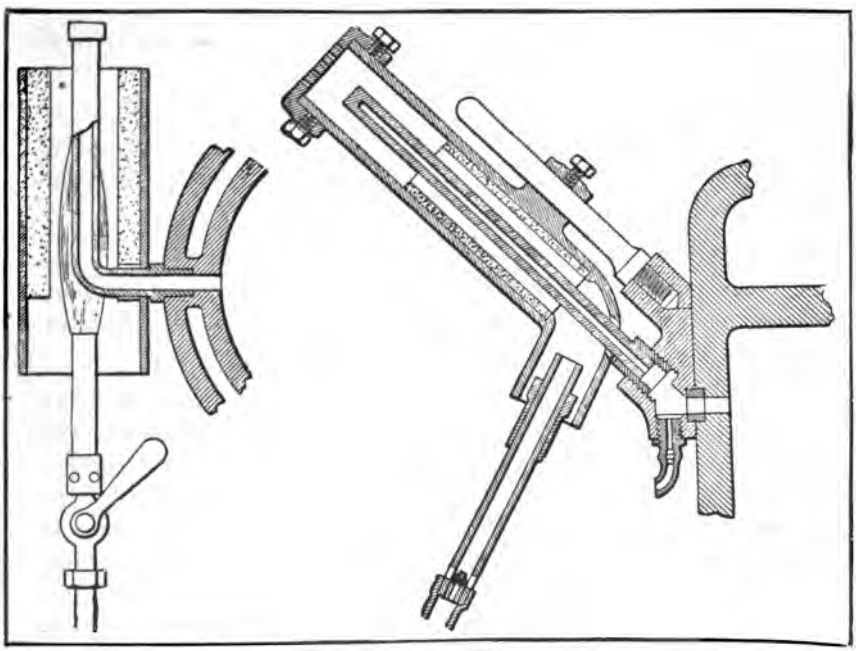


Fig. 75.—Showing Construction of Hot Tube Formerly Used in Igniting Gases in Automobile Cylinders But Now Confined to Large Stationary Engines Employing Low Grade Fuel.

Fig. 75-A and also at Fig. 76, is a modification of the hot tube method, inasmuch as a certain portion of the cylinder head, usually in the form of a hollow ball, is heated by the flame of a torch in order to get hot enough to start the engine. After the engine had been running for a few minutes the external source of heat could be re-

moved and enough heating effect would be obtained from the high temperature of the exploding charges to maintain the heat of the head.

Q. What is the main objection to the ignition methods previously named?

A. One of the main disadvantages of the open flame, hot tube, and hot head methods of ignition which they share in common, was that considerable difficulty obtained in attempting to vary the time of ignition and obtain some degree of engine control by this means.

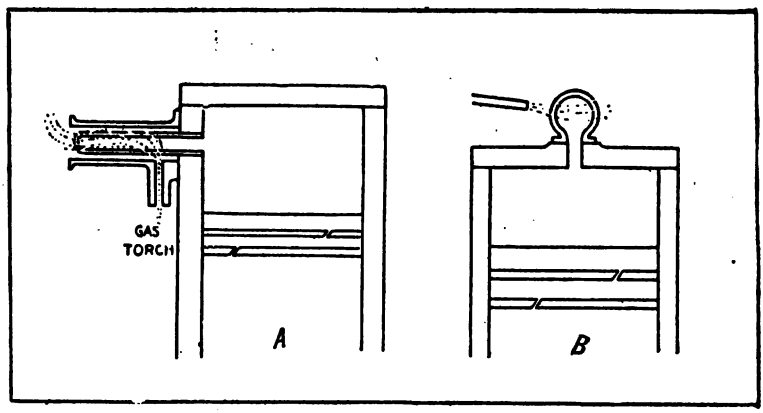


Fig. 75A.—Diagrams Outlining Principal Methods of Exploding Charge by Heat. A—Hot Tube System. B—Hot Bulb Method.

Q. How can gas charge be exploded by electrical means?

A. Three methods of producing heat by electric current have been used. These are outlined at Fig. 76-A. The diagram at *A* shows the first electrical ignition system in which a coil of wire was inserted in the cylinder and heated by passing a current of electricity through it until it was hot enough to explode the compressed gas. A defect of this method of ign tion was the rapid deterioration of the ignition coil and the necessity for frequent replacement of these members. In the methods outlined at *B* and *C*, an electric spark is produced in the cylinder at just the time it is desired to explode the compressed gas.

Q. How is spark produced in cylinder?

A. There are two methods of causing an electric spark to occur in the combustion chamber. That outlined at *B* in Fig. 76-A involves a separation of two contact members, through which a current of electricity is flowing. The spark is produced when the points separate. That outlined at *C* is known as the high tension system and a spark overcomes the air space between the points of the spark plug because it has sufficient power or pressure to overcome the resistance at that point.

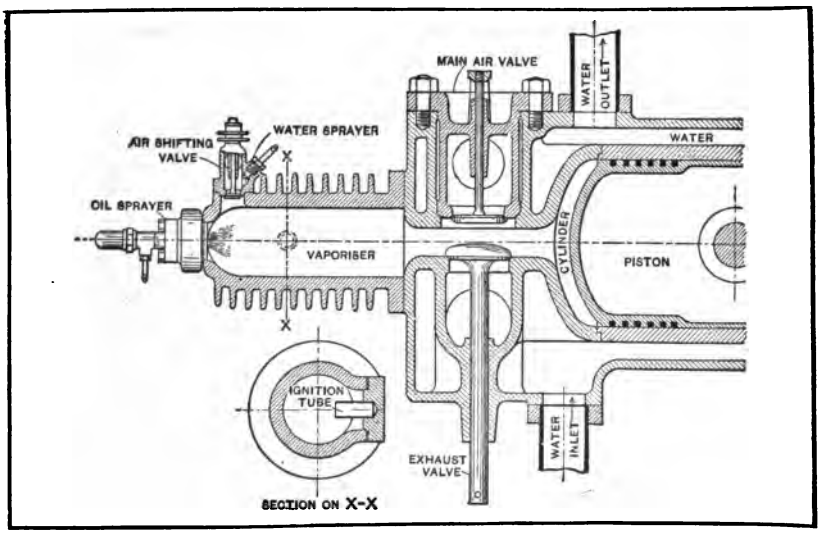


Fig. 76.—Section Through Vaporizer and Valve Chamber of Stationary Engine Utilizing Hot Tube Ignition.

Q. What are the important advantages of the electrical ignition systems?

A. Electrical ignition systems, as a rule, are easily controlled, ignite the charge unfailingly and exactly when desired, and are the most reliable of the ignition methods that permit flexible engine operation.

Q. Why is variable ignition desirable?

A. Variable ignition is necessary because, on modern high speed

automobile motors, it is necessary to fire the charge earlier when the engine is running fast than when it is running slow.

Q. Why should spark be retarded when starting an engine?

A. When an engine is started by hand it is desirable to have the ignition late or retarded in order that the gas will not explode until the piston has started down on its power stroke. If the explosion occurred before the piston started down it might be driven around in the opposite direction to that it should go and the operator would be injured by the reversal of motion of the crank or flywheel.

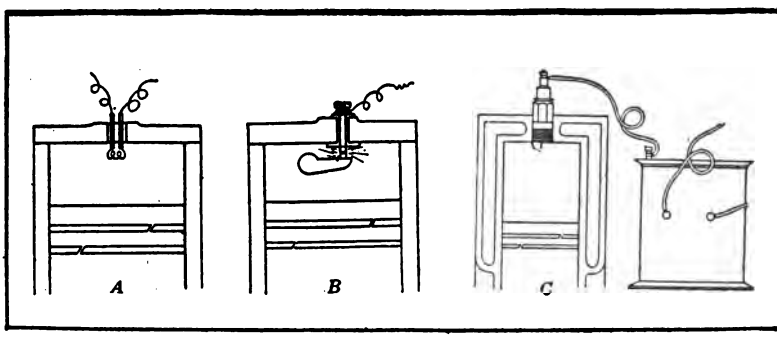


Fig. 76A.—Diagrams Outlining Possible Methods of Electrical Ignition. A—By Incandescent Platinum Wire. B—By Make and Break or Low Tension Spark. C—By High Tension or Jump Spark.

Q. Why is it necessary to advance spark?

A. When the engine speed is increased faster than a normal number of revolutions, a greater number of explosions occur in a given space of time than when the engine is running slowly. The gas requires a certain amount of time to become ignited, and when an engine is running faster and more gas charges must be exploded, it is necessary to start the ignition earlier, which means that the spark time in relation to the crankshaft or piston travel must be advanced.

Q. Why is throttle control alone inadequate?

A. Controlling the engine speed by varying the amount of gas does not permit exploding the gas charges fast enough in order to speed up the engine.

Q. What would be the effect when using throttle control without variable ignition at various engine speed?

A. When a set spark is used it is customary to set the time of ignition so that a condition best suited for normal running conditions is obtained. This means that the spark is set too early to insure absolute safety when starting the engine and yet it is too late to permit the engine attaining its highest possible number of revolutions. If the spark is set a little late and speed is desired it will be noticed that the engine heats up with full throttle openings and yet it is liable to fire back due to an advanced position when attempt is made to start the motor.

Q. Is set spark used to any extent?

A. Very few automobiles are controlled by varying the supply of gas solely, though in a few cases where magneto ignition is employed the spark time is fixed and engine speed is regulated solely by controlling the admission of explosive vapor to the cylinders. This is possible because a magneto will generate more current and produce a spark of greater intensity as its speed of rotation is increased. This means that a hotter spark is present in the cylinder at high speed and in a measure this provides for positive ignition and corresponds to some extent to advancing the time of ignition. Practically all automobiles in use at the present time are provided with variable ignition systems, and do not depend on throttle control alone.

LESSON EIGHT

PARTS OF THE IGNITION SYSTEM AND THEIR PURPOSE

Q. Name the principal parts of an electrical ignition system.

A. The principal parts of typical ignition systems of the high tension type are outlined at Figs. 77 and 78-A. The prime requisite is a source of electrical current, a device by which it will produce a spark in the combustion chamber, auxiliary devices for intensifying it or increasing its value, a suitable timing appliance to insure that the spark will take place in the cylinder only at the proper time and wires or conductors to permit the electrical energy to flow from one unit of the ignition system to the others. The important parts of a high tension system are: The battery or other current producer; the timer, which regulates the time of ignition; the induction coil, which is a transformer to step up or increase the current pressure of the batteries; and the spark plug which is screwed into the combustion chamber, and between the points of which the igniting spark takes place.

Q. What are the requirements of the current producer?

A. The current producer must supply the electrical energy required to produce the spark, and must be reliable in action, as well as relatively simple in construction.

Q. How is the current of electricity transmitted?

A. The electrical energy is transmitted over a number of metal conductors or wires insulated from each other and the metal parts of the engine to form circuits.

Q. What is a circuit?

A. A circuit is a path for the electric current to flow over and may be composed entirely of wire or of wire which joins various

elements or devices interposed so that the current must pass through these before it will complete its circuit.

Q. What is the difference between a closed and open circuit?

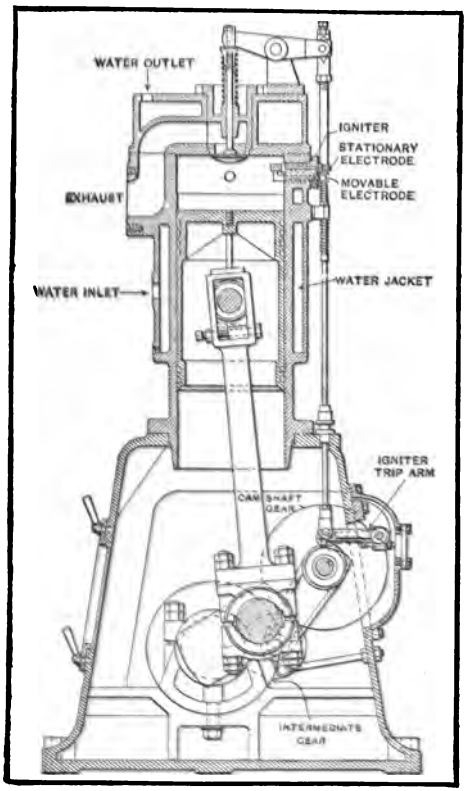


Fig. 77.—Vertical Engine Employed in Stationary Service Showing Method of Using Low Tension Ignition System.

A. A closed circuit is one that provides an unbroken or continuous path for the transmission of electrical energy while an open circuit is one in which there is a gap or resistance sufficiently great to prevent the electrical energy from passing between the various members comprising the circuit. Electricity can flow only over a closed circuit, except in cases where the pressure of the current is great enough so that it may overcome or bridge the gap or resistance in an open circuit.

Q. How many circuits are there in the usual ignition system?

A. There are two circuits in the conventional high tension ignition systems, these being the primary and secondary circuits respectively.

Q. What parts are included in the primary circuit?

A. The primary circuit includes the source of current or battery, the switch, the ignition timer and the primary winding of the transformer or induction coil. (See Figs. 77A and 78.)

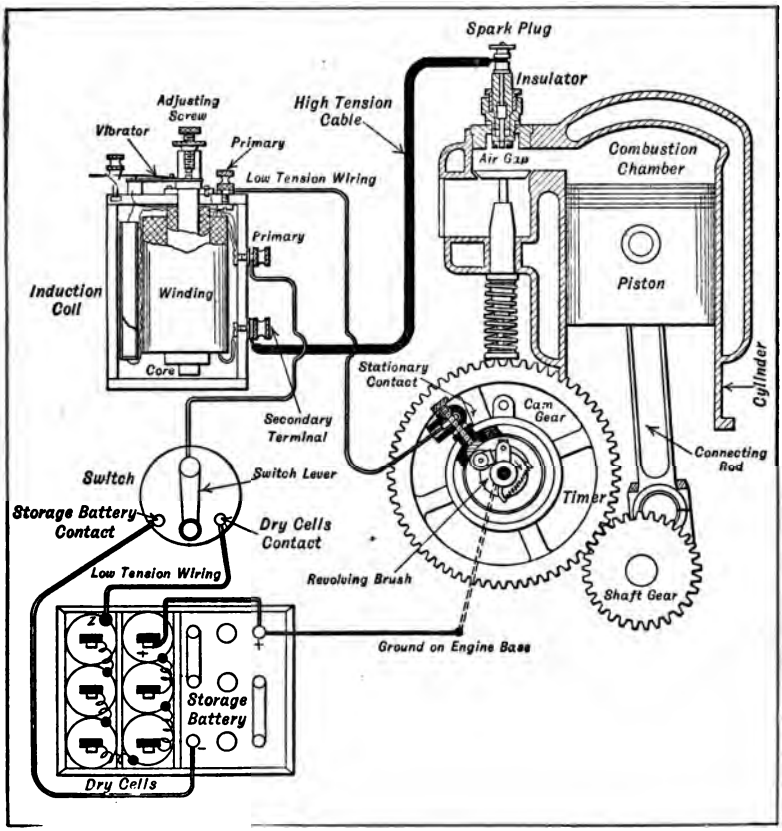


Fig. 77A.—Simple High Tension Ignition System for One Cylinder Motor Showing Arrangement and Wiring of Principal Parts.

Q. What parts are in the secondary circuit?

A. The secondary circuit includes the high tension winding of the induction coil and the spark plug.

Q. Describe parts of simple battery ignition system.

A. A simple battery ignition system for a single cylinder engine is shown at Fig. 77A and a corresponding system for a two cylinder engine is outlined at Fig. 78. The current supply is obtained from two sets of cells, one of these being a dry battery, the other a storage

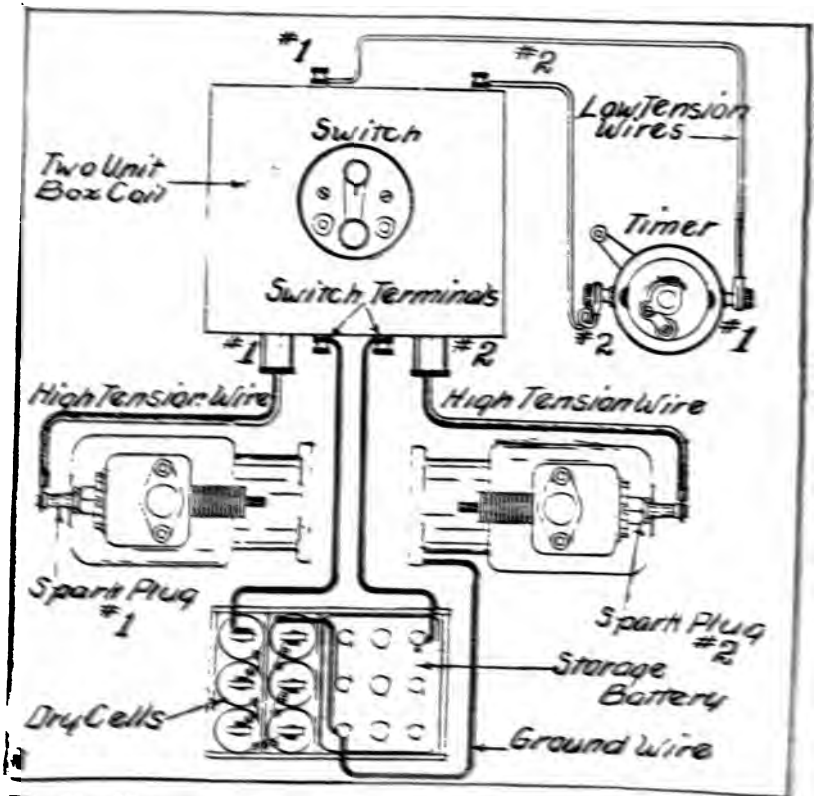


Fig. 78.—High Tension Ignition System for Two-Cylinder Opposed Motor.

battery. One wire from the negative or minus terminal — of each battery leads to a button on the switch. The plus terminal — or positive, as it is commonly termed, of each battery is grounded to the engine frame. A single wire leads from the top of the switch to one of the primary terminals of the induction coil. The other primary terminal of the induction coil is connected to the insulated terminal on the contact maker or timer. A heavily insulated wire joins the secondary terminal of the induction coil with the insulated terminal of the spark plug.

The action of this method of ignition may be easily understood

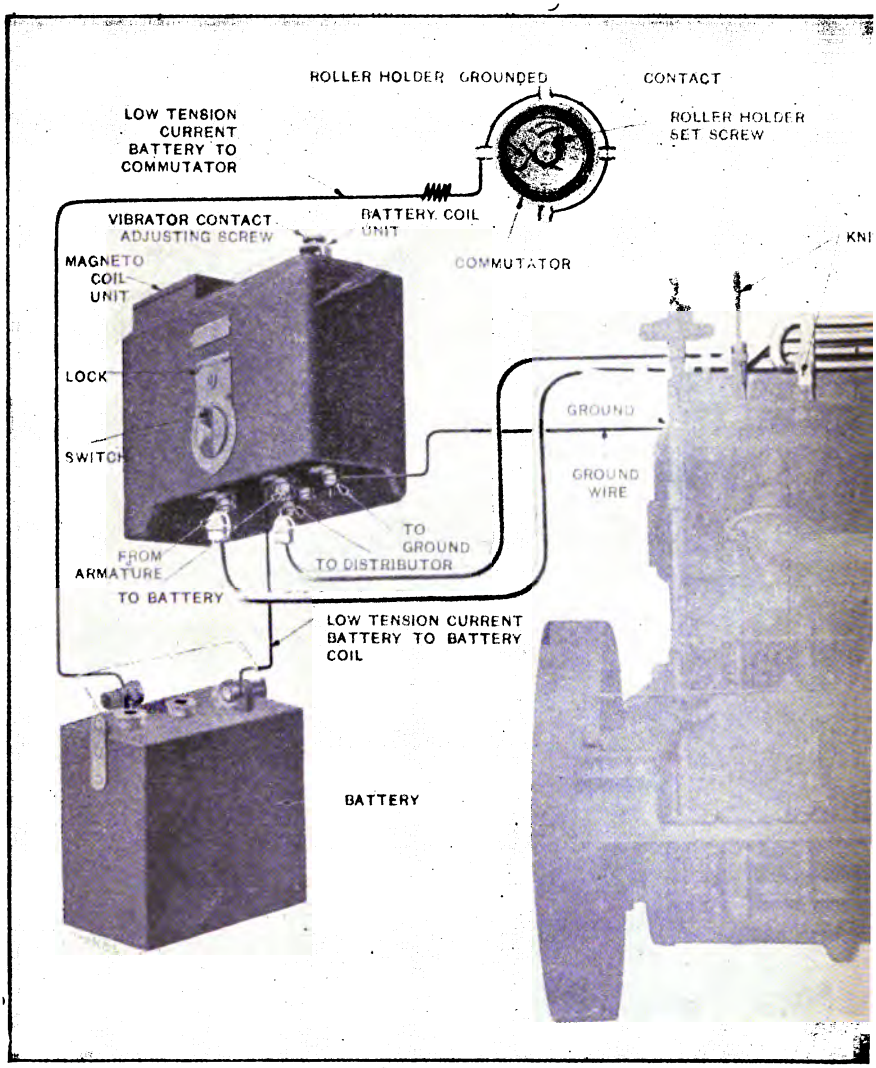
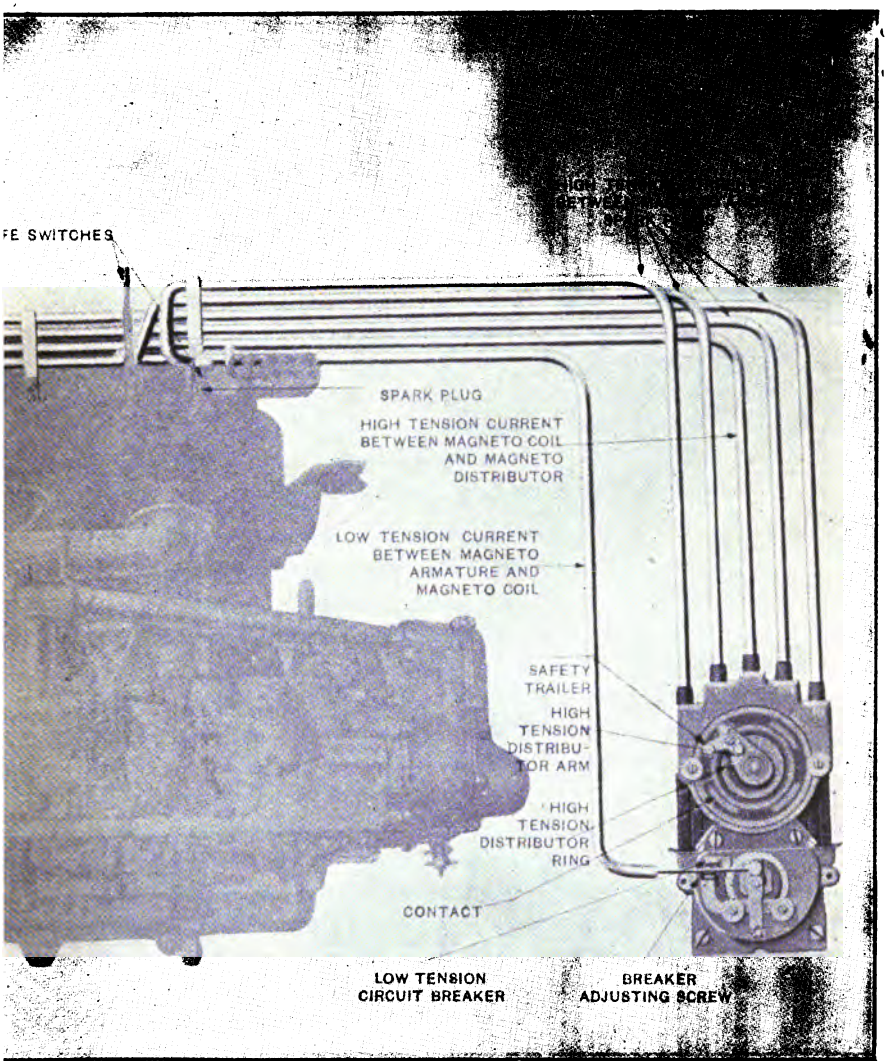


Fig. 79.—Ignition System of Packard Motor Truck in Whicl


FE SWITCHES
SPARK PLUG
HIGH TENSION CURRENT BETWEEN MAGNETO COIL AND MAGNETO DISTRIBUTOR
LOW TENSION CURRENT BETWEEN MAGNETO ARMATURE AND MAGNETO COIL
SAFETY TRAILER
HIGH TENSION DISTRIBUTOR ARM
HIGH TENSION DISTRIBUTOR RING
CONTACT
LOW TENSION CIRCUIT BREAKER
BREAKER ADJUSTING SCREW

Batteries and Magneto are Employed for Furnishing Current.

by referring to Fig. 77A. The revolving brush of the timer is turned by the cam shaft which revolves at half the engine speed. If the switch lever is placed on the storage battery contact, the current from the storage battery will flow through the primary winding of the induction coil only at such times that the circuit is closed by the revolving brush member of the timer coming in contact with the insulated segment on the timer case, and thus closing the circuit so the electrical energy has nothing to impede its passage from the battery, through the timer and primary winding back through the switch and return to where it started from. When the low tension current flows through the primary winding of the induction coil, a secondary current of high pressure is induced in the secondary winding of the transformer coil, and is led to the spark plug where it must leap the air gap between the electrodes and produce a spark before it can return to the winding again through the medium of the metal of which the engine is composed, which thus acts as a common ground for both primary and secondary currents.

Q. What is the function of the switch?

A. The switch is an easily controlled member that permits one to have an open or closed circuit at will. In most ignition systems, two switches are provided, one under the direct control of the operator serves as a master switch, while an auxiliary member commonly termed a "timer" and operated by the engine acts in conjunction with it to produce a closed circuit only at such times that a spark is needed in the cylinder. It will be evident that a closed circuit is obtained only when the members of both switches are in metallic contact. The master switch in most cases serves to couple either source of current to the other appliances of the ignition system. When the engine is once in motion and the timer is closing the circuit automatically, opening the master switch will prevent the electrical energy from flowing, interrupt the spark in the cylinder and stop the engine. The timer which is outlined at Fig. 81 is thus a mechanically actuated automatic switch that closes the circuit only at such times that a spark is needed in the cylinder to explode the gas.

Q. What is the spark plug?

A. As previously outlined, the spark occurs in the cylinders

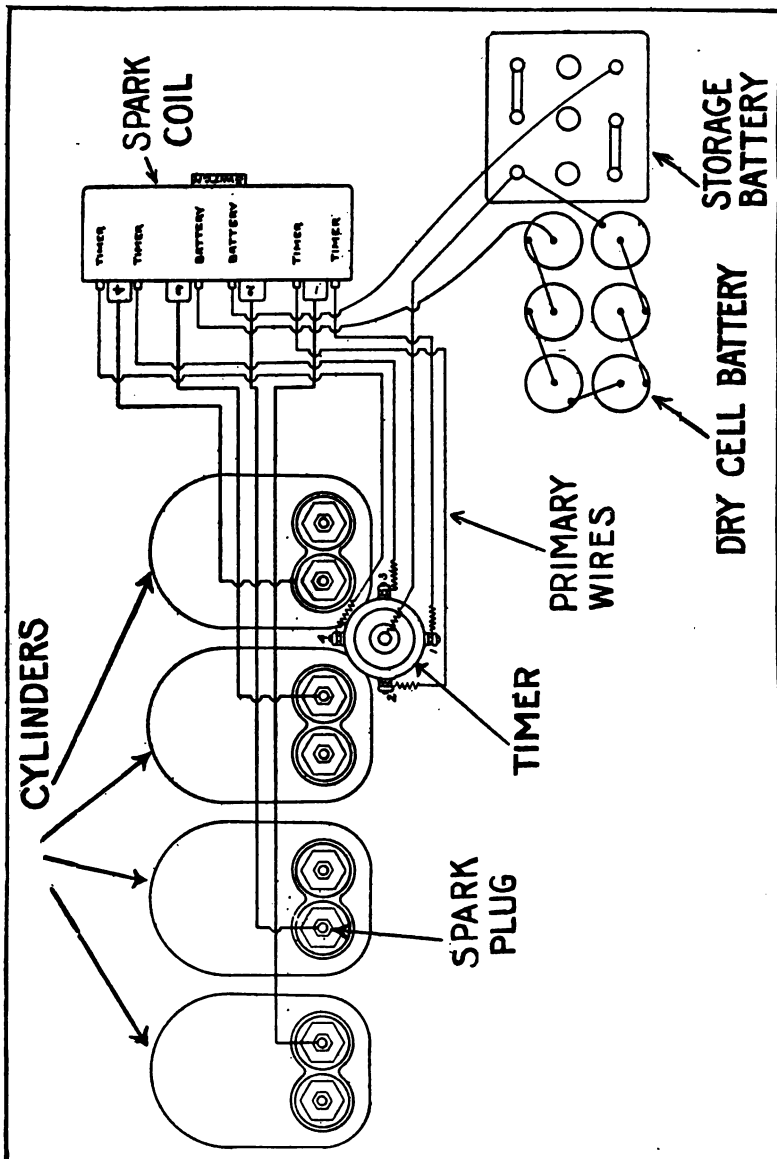


Fig. 80.—Diagram Showing Parts of Typical Four-Cylinder High Tension Ignition System Utilizing Batteries for Current Supply.

(when a high tension system is used) between the electrodes or points of a device which carries them and which may be easily screwed into the combustion chamber so that when the spark points are introduced into the interior of the motor there is no opportunity for the escape of gas.

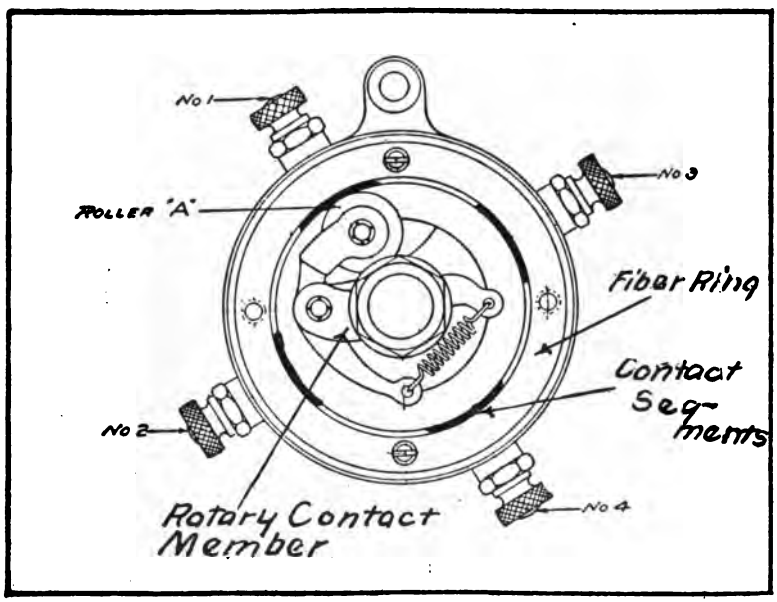


Fig. 81.—Roller Contact Timer Used for Distributing Current Derived from Ford Magneto or Battery to Individual Units of Spark Coil.

Q. How many types of spark plugs are used?

A. Spark plugs are divided into two main types, the simple form as shown at *A* and *C*, Fig. 82, and the priming type as outlined at *B*, Fig. 82, and in illustrations at Fig. 83. The priming type is a combination form which has a small petcock, or valve, through which gasoline may be introduced into the combustion chamber to facilitate starting in cold weather when it is difficult to draw in a proper charge of gas from the carburetor.

Q. Describe important parts of spark plug.

A. Conventional spark plugs are composed of a steel or brass

body having an external thread at its lower end which screws into the cylinder and an internal thread at its upper end in which the gland or packing nut that holds the insulator and insulated electrode assembly in place, is screwed. The grounded electrode usually forms part of the plug body, while the central electrode is invariably kept from metallic contact by means of an insulator of porcelain, as shown at Fig. 82-A, or combination mica and porcelain, as shown at Fig. 82-C. The electrodes are separated by an air gap.

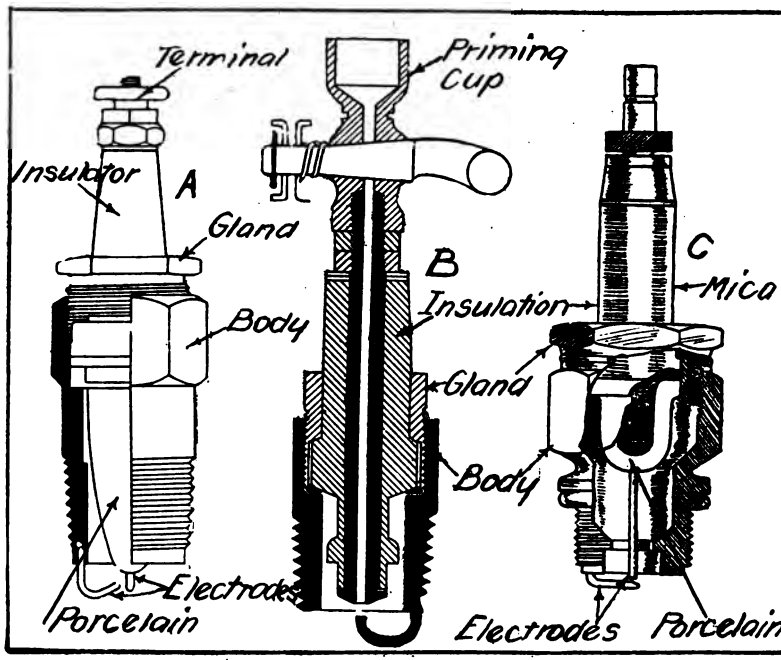


Fig. 82.—Views Detailing Construction of Conventional Spark Plug. A—Member With Porcelain Insulator. B—Heinze Priming Cup Type Utilizes Mica Insulation. C—Plug Using Combination Porcelain and Mica Insulation.

Q. What is the proper amount of air gap between electrodes?

A. The electrodes of plugs used with magneto ignition system are usually separated about 1-32 of an inch, while those of a plug intended for battery and coil current may be separated by an air gap of 1-16 inch.

Q. What is the induction coil?

A. The induction coil is a transformer of the "step-up" type which changes the direct current from the batteries, which does not have sufficient pressure to overcome the resistance of the air gap at the spark plug, to an alternating current having higher pressure to jump the air gap and produce a spark.

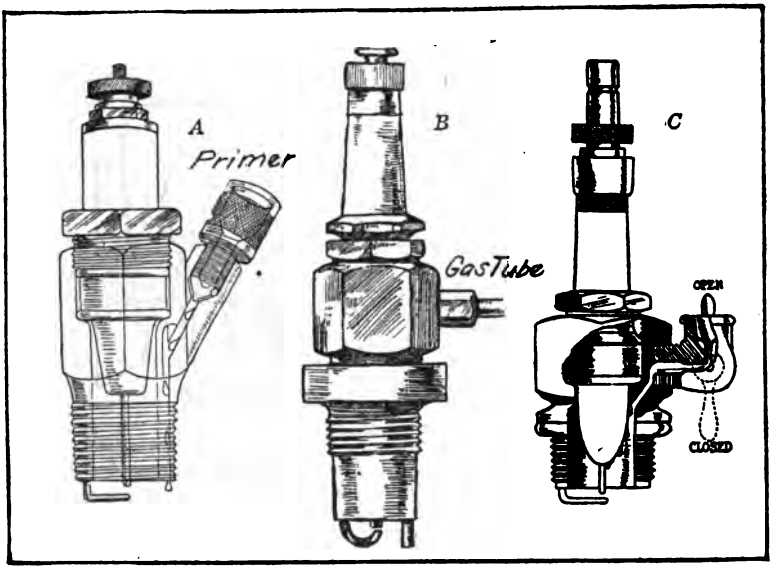


Fig. 83.—Types of Spark Plugs That Permit Priming the Cylinder With Gasoline or Acetylene Gas When Combustion Chamber is Not Provided With Compression Pet Cocks.

Q. Name the principal parts of an induction coil.

A. The components entering into the construction of a typical induction coil are clearly indicated in diagram form at Fig. 84. An induction coil consists of a core, primary and secondary windings, vibrator, and condenser.

Q. What is the core made of?

A. The core is composed of a bundle of short pieces of soft iron wire closely bound together.

Q. What is the primary winding composed of?

A. The primary winding is composed of from two to four coils or layers of silk insulated wire about 16-18 gauge such as used to wind around electro-magnets.

Q. What is the vibrator?

A. The vibrator is composed of a hammer, or armature member carrying one platinum contact point and a movable adjusting screw

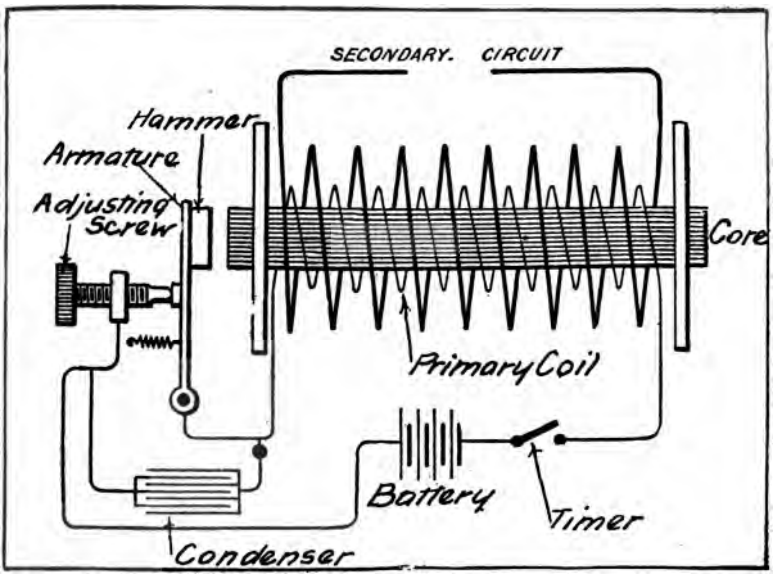


Fig. 84.—Diagram Showing Relation of Parts of Induction Coil.

carrying another platinum contact point, the assembly forming an automatic circuit breaker. When the current of electricity from the battery passes through the primary coil it energizes the core which becomes a magnet. The core attracts the hammer of the armature and breaks the contact between the platinum point on the armature spring and that on the adjusting screw. As the battery current must pass through these points before it reaches the primary winding, as soon as the hammer is drawn toward the core the circuit is broken, the core ceases to become a magnet and the armature

flies back again, thus re-establishing electrical contact. It will be apparent that the circuit can be broken and re-established many times per second, and as each interruption in current flow induces an impulse in the secondary winding, the greater the number of vibrations of the armature the higher the value of the induced secondary current.

Q. How is the secondary winding made?

A. The secondary winding is composed of a large number of coils or layers of very fine, thread-like insulated wire carefully wound and thoroughly insulated from each other. The greater the number of turns of secondary wire in proportion to the number of layers of primary wire, and the greater the relative difference between the size of primary and secondary wires, the higher the value of the induced secondary current in proportion to the pressure of the primary current. The voltage of the primary current may be increased several thousand times by properly proportioning the primary and secondary windings, and at the same time it will have sufficient heating value to explode the gas as it overcomes the resistance of the air gap between the spark plug electrodes.

Q. What is the condenser and how is it made?

A. The condenser is a simple assembly introduced between the adjusting screw and armature spring in such a way that it is in shunt or parallel connection with the contact points. It is composed of two sets or layers of tin foil insulated from each other by layers of wax paper. Alternate sheets are joined together so there is no electrical connection between one set of tin foil sheets and the other. The function of the condenser is to absorb any excess current present between the platinum points that would tend to produce a spark as they separate. This excess current is the result of self-induction of one coil of the primary winding upon the neighboring one, and would tend to oppose the passage of the current from the battery if it was not absorbed and stored in the tin foil layers of the condenser. If no condenser is provided, the spark between the points would pit them and burn them to such a degree that prompt vibrator action would be prevented because of the uncertainty of metallic contact when the platinum points came together. This

would result in sluggish vibrator action and diminish strength of secondary current.

Q. Describe induction coil action.

A. The diagram at Fig. 85 will assist the reader in obtaining knowledge of induction coil action. Here a solenoid or hollow coil of wire is shown attached to a sensitive form of current indicator. A primary coil, which contains a core of soft iron wire, is depicted as just entering the solenoid. The ends of the primary winding are joined to a simple battery composed of two dry cells. A current of electricity is thus flowing through the primary coil all the time, and the core member is a magnet from which magnetic influence is radiated. When the primary coil assembly is first introduced into the solenoid, the needle of the current indicator will move, thus showing that another current of electricity, other than that flowing through the primary coil from the battery, has been induced in the secondary winding or solenoid. If the primary coil and core assembly is allowed to remain inside of the solenoid, the current indicator needle comés to rest, showing that there is no current induced in the solenoid. If the primary coil be withdrawn from the interior of the secondary winding, another movement of the current indicator needle in the opposite direction to that which it moves when the primary coil was introduced will show that another impulse or induced current has been produced by withdrawing the primary coil assembly. If the primary coil could be thrust in and out of the secondary coil sufficiently fast, practically a continuous flow of alternating current would be induced in the solenoid.

The induced current is produced by magnetic influence from the core, and obviously if the primary coil was allowed to remain in the secondary coil and the electric current from the battery interrupted and the flow re-established often enough, we would have practically the same effect as though the primary coil was thrust in and out of the secondary coil a number of times corresponding to the making and breaking of the primary circuit at the batteries. It will be apparent that the induction coil assembly outlined at Fig. 84 is practically the same as that shown at Fig. 85, except that the primary coil is a fixed member inside of the secondary winding and the number of current interruptions through the primary coil is obtained

by means of a very rapid automatic magnetic circuit breaker or vibrator, the action of which has been previously considered.

Q. Describe timer construction.

A. The usual form of timer as outlined at Fig. 81 is composed of a fiber insulating ring which carries a number of metal contacts which are out of electrical connection with each other and with the metal body of the timer. The rotary contact member revolves in the interior of the insulating fiber ring and makes contact with the segments as it revolves. Each segment communicates with one of

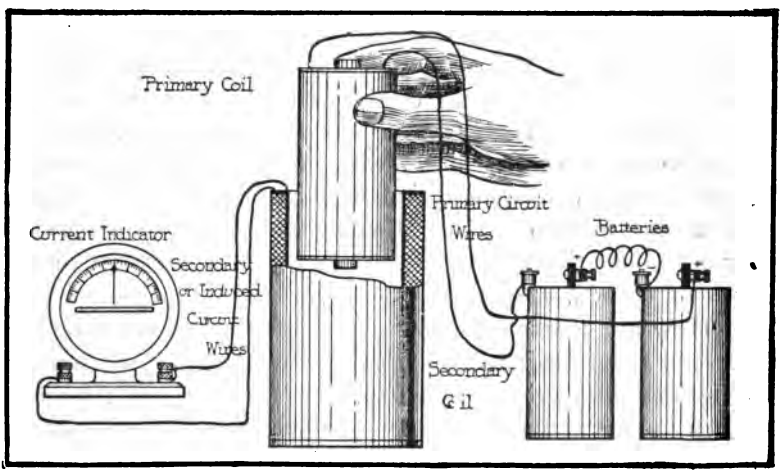


Fig. 85.—How Current is Induced in Secondary Coil by Varying Flow of Energy Through Primary Coil.

the units of an induction coil and the number of segments and terminals used is determined by the number of cylinders to be fired. The device shown is adapted for a four cylinder motor.

Q. What is the difference between a single cylinder engine timer and one for multiple cylinder ignition?

A. The difference is only in the number of insulated contacts. The timer intended for the multiple cylinder engine having the greater number. A one cylinder timer has but one insulated contact segment and one external primary terminal. As the number of

cylinders increase additional ccntacts are provided, one for each added cylinder.

Q. Are timers used only with primary current?

A. Timers may be used in connection with either primary or secondary current, though when used for distributing the high tension current, they are termed "secondary distributors."

Q. What is the difference between a primary timer and a secondary distributor?

A. In a primary timer the revolving contact element is grounded or attached directly to the metal parts of the engine. In a secondary distributor the revolving brush or contact member is well insulated from the engine and is coupled directly to the source of current or secondary winding of the induction coil. Special care must be taken to insulate the terminals and contacts of a high tension distributor on account of the ease with which the high voltage current overcomes resistances that would effectively bar the progress of the low tension current. Usually a secondary distributor includes a primary timing arrangement as well when used in connection with a battery ignition system.

Q. How are contacts in timers and distributors spaced?

A. In a timer intended for a two cylinder motor the contacts are spaced according to the arrangement of the cranks on the crankshaft. If the motor is a double opposed form or a two cylinder vertical type with both connecting rods attached to a common crank pin, the contacts are separated by 180 degrees or are spaced on halves of the circle. If the engine is a two cylinder vertical or V type, the contacts are not evenly divided but are separated by spaces of 270 and 90 degrees respectively. The contacts of a three cylinder timer are spaced on thirds of the circle or 120 degrees apart. Those of a four cylinder timer are separated by a space of 90 degrees and are spaced on quarters of the circle. (See Fig. 81.) For a six cylinder engine the contacts are spaced on sixths of the circle, which means that they are 60 degrees apart.

Q. What is the difference between primary and secondary wire and why are they different?

A. Primary wire carries current of low voltage that does not

short circuit easily, so the insulation is not nearly as heavy as that on the secondary or high tension current conductors. A primary wire is insulated with but one layer of rubber; whereas a secondary wire has several of insulating compound. A number of wires are shown at Fig. 86. Those at *A*, *B*, and *C* are heavily insulated conductors used to convey high tension energy, while the wires with the lighter insulation, as shown at *D* and *E*, are suitable for primary circuits. A number of primary leads are sometimes joined together and though separately insulated, are run through a common conduit, or insulating tube, as shown at *F*. When used in this manner the inner insulation of the different wires is usually of different colors so they may be easily recognized when making connections.

Q. How is electricity measured?

A. The strength, quantity, potential and other characteristics of the electric current may be readily determined by simple meters provided with a pointer and a calibrated or graduated scale so the readings can be made easily.

Q. What is the volt?

A. The volt is the unit of pressure and may be taken as corresponding to the head or pressure of water.

Q. What is the ampere?

A. The ampere is the unit of current quantity and corresponds to the amount of electricity flowing through a circuit. A current may have a large amperage, which means that a large volume is flowing, and yet it may have low pressure or voltage. The reverse condition may also obtain and a current of high voltage may not have much amperage.

Q. What is the watt?

A. The watt is the unit indicating the amount of electricity or the value of the current flow. A current of one ampere flowing at a potential or pressure of one volt has a value of one watt. There are 746 watts to the electrical horse-power. In all cases the amount of current consumed by any piece of electrical apparatus is indicated in watts, which is always the product of the number of amperes of current times the potential or voltage.

Q. What is the ohm?

A. The ohm is the unit by which the resistance anything offers to the passage of the electric current is measured. To overcome one ohm of resistance it will take a current of one ampere at a pressure of one volt.

Q. How are dry batteries measured?

A. Dry batteries are measured as shown at Fig. 87 by means of a simple device which measures the amperage or current output, and which is called an "ammeter." A standard 6″x2½″ dry cell in good condition should indicate a current strength of from 20 to 25 amperes. The voltage of a dry cell varies from 1.25 to 1.5 volts.

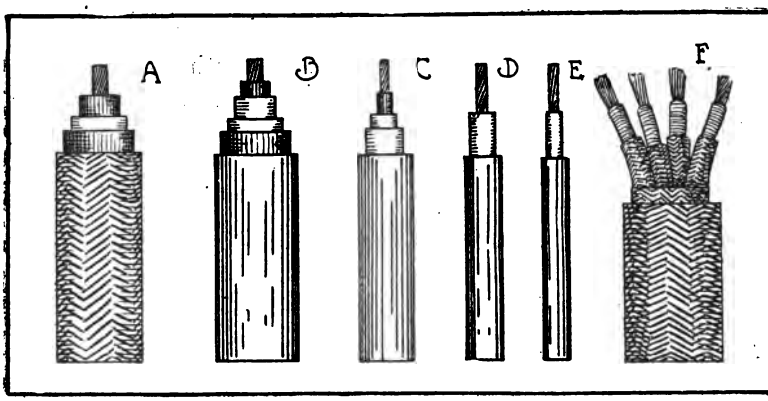


Fig. 86.—Forms of Primary and Secondary Electric Current Conductors.

Q. How is the current strength of storage batteries determined?

A. Storage batteries are measured with a voltmeter, which is an instrument similar in construction to an ammeter with the exception that it is designed to register the pressure instead of the quantity of the electric current flowing through it. A single cell of a storage battery is supposed to test 2.2 volts when fully charged, which means that a 2 cell battery will indicate 4.4 volts while a 3 cell battery shows 6.6 volts. The ordinary form of battery testing ammeter should never be used in testing a storage battery, be-

cause its construction is such that it will practically short circuit the battery and it may produce buckling of the plates owing to the rapid discharge of the stored energy.

Q. How can current consumption of induction coil be found?

A. The method of using a simple current indicator to show the amount of electricity used by an induction coil is clearly outlined at Fig. 88. The instrument shown is a low reading ammeter, and is so arranged that the terminal end may be inserted between the switch button and switch lever, while the coil is in operation. The amount of current drawn by each unit can be easily determined by testing out but one unit at a time. This can be easily done by raising the contact screws of the vibrators so that they do not touch the contact on the vibrator blade, except on the unit that is to be tested. The engine is then cranked over by hand and the amount of current consumed by the coil vibrator will be clearly indicated as soon as contact is established at the timer. The ordinary induction coil unit consumes from .5 to 1 ampere, and if the current consumption is greater than this, the tension of the vibrator spring should be lessened so that less current will be necessary to energize the primary winding.

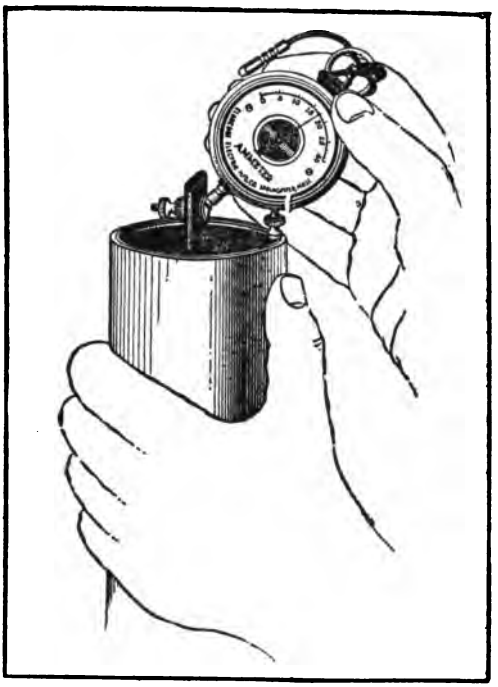


Fig. 87.—Method of Testing Current Strength of Dry Cell With Ammeter.

LESSON NINE

CURRENT PRODUCERS: BATTERIES, DYNAMOS AND MAGNETOS

Q. What is the simplest method of producing electricity?

A. The simplest method of producing electricity is by the use of a primary or secondary battery which generates electrical energy by the chemical combustion of one of the elements or plates of the battery.

Q. What is the cheapest method of producing electricity?

A. Electricity may be produced at lower cost by magnetic machines which change mechanical power into electricity.

Q. How many classes of batteries are used?

A. Two general classes of chemical current producers are commonly used, these being primary batteries and secondary batteries.

Q. What is a primary battery?

A. A primary battery is one in which electricity is generated by the direct chemical action of the electrolyte on one of the plates composing the cell. A primary cell has positive and negative elements; that attacked by the electrolyte is usually termed the "negative" plate and is made of zinc, either in the form of a plate or a rod. The po itive element is of some substance that is not affected by the electrolyte and which serves as a collecting member for the electricity generated. In a primary battery electricity is produced at the expense of decomposition of the zinc plate and deterioration of the electrolyte. When a primary battery is exhausted or no longer capable of producing electricity, it must be practically rebuilt in order to extend its life. New electrolyte and zinc must be added to replace that used before the cell will give any more electricity.

Q. What is a secondary battery?

A. The secondary battery, commonly called the "storage battery" in America and the "accumulator" in Europe, is a form of chemical current producer in which the elements can be restored to their former condition when exhausted by passing a current of electricity through the battery in a direction opposite to that of the current flow normally given out by the battery. As a battery of this form can only produce electricity after it has been energized or charged by a current from some extraneous source, such as a primary battery or mechanical generator, it is called a "secondary" battery.

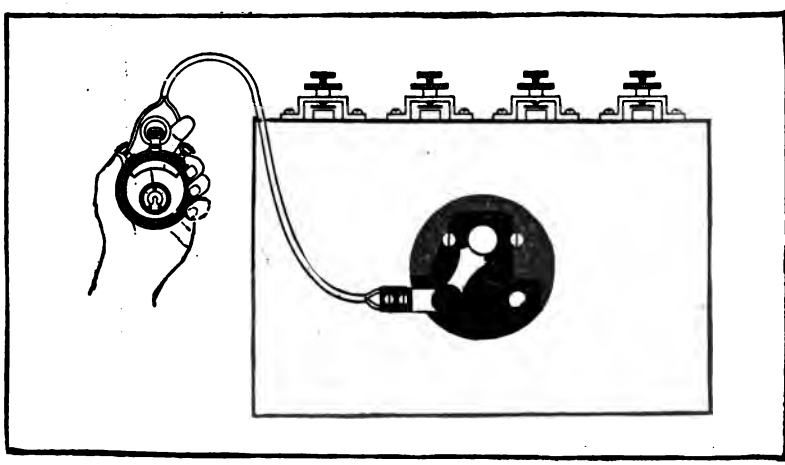


Fig. 88.—Outlining Method of Determining Current Consumption of Induction Coil by Using Low Reading Ammeter.

Q. What is a dry battery?

A. A dry battery is the form of primary cell in which the liquid electrolyte is replaced by some form of jelly or other substance to absorb the liquid so it cannot splash out while the automobile is in operation.

Q. Describe construction of typical dry cell.

A. A part sectional view of the conventional form of dry cell is outlined at Fig. 89. The container or shell is made of zinc and

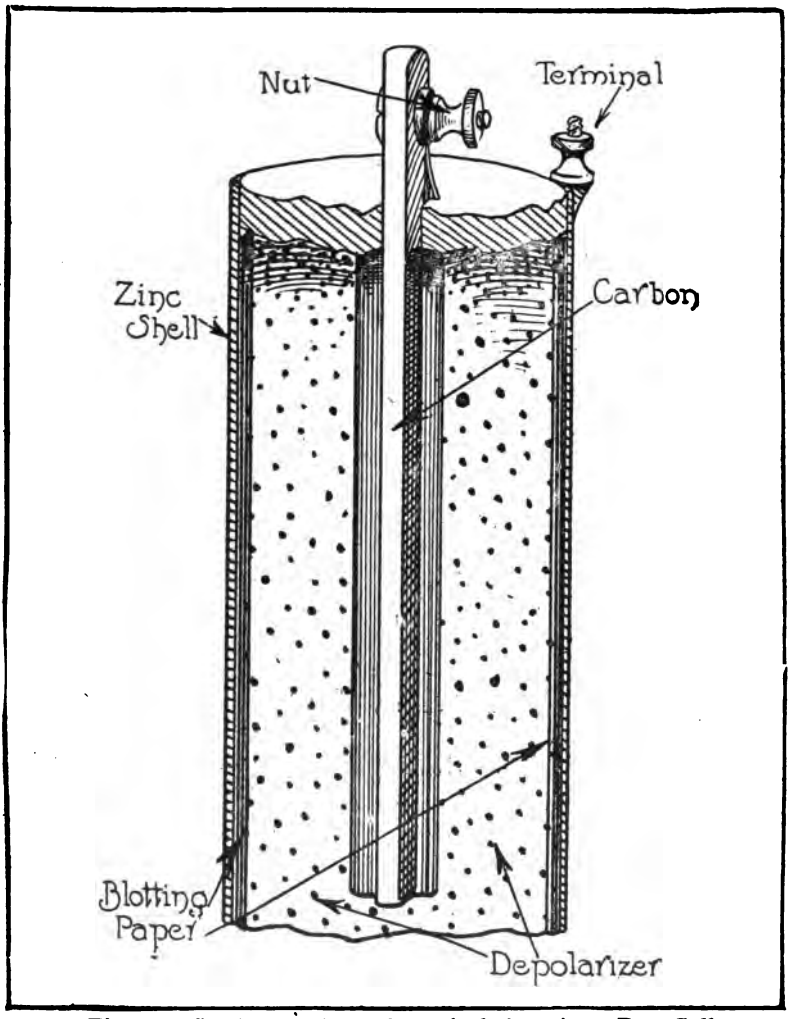


Fig. 89.—Sectional View of Typical American Dry Cell.

serves as the negative element, while a stick of carbon placed in the center of the zinc shell and kept from contact with the metal serves as a positive element. The electrolyte or exciting material is absorbed by blotting paper, several layers of which are closely wound

around the inside of the zinc shell. This places the electrolyte directly in contact with the metal it acts on. The carbon rod is surrounded by a depolarizing material which keeps the cell active for longer periods than if the electrolyte alone was used.

During the action of the cell, or whenever the zinc and carbon terminals are joined together to form a closed circuit, the chemical action of the electrolyte on the zinc liberates hydrogen gas which would clog or retard the action of the cell if allowed to accumulate on the carbon plate. The depolarizing medium is some chemical rich in oxygen, and its purpose is to liberate oxygen gas while the cell is in operation, which combines with the hydrogen in proper

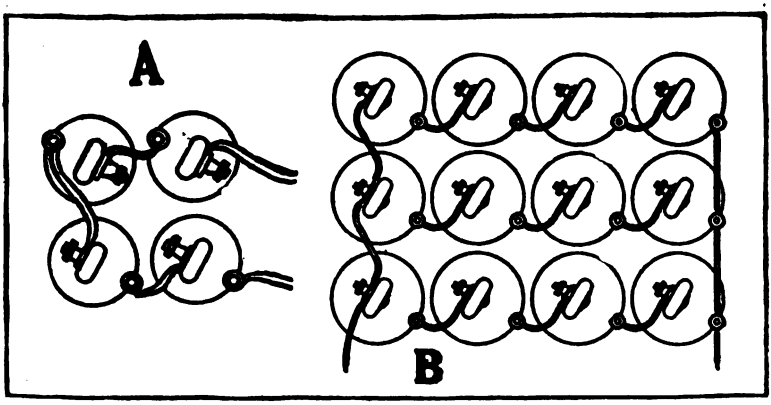


Fig. 90.—Methods of Joining Dry Cells for Ignition Service. A—Four Cells in Series Connection. B—Twelve Cells in Multiple Series Connection.

proportions to form water. The water thus formed is of distinct value, inasmuch as it keeps all parts of the cell moist and lowers the internal resistance. The top of the cell is sealed with a thick layer of pitch to prevent escape of the gases and to retain the elements of which the cell is composed in the zinc shell as well as to keep the elements separated.

Q. How are dry cells used?

A. Dry cells are generally employed in sets, so that batteries having different values, as regards current pressure or quantity, are produced. They may be wired together in series, in multiple,

or in series-multiple connection. The latter method is that generally used.

Q. Describe series connection.

A. The method of connecting dry cells in series is clearly outlined at Fig. 90-A. When joined in this manner the negative terminal of one cell is always joined to the positive or opposite terminal of the neighboring one. For instance, the zinc of one cell is always connected to the carbon of the next member. When cells are joined this way, a battery is produced which has a voltage equal to that of one cell times the number of cells joined together, but the amperage of only one cell.

Q. Describe multiple connection.

A. Cells are connected together in multiple only when a current of heavy amperage and low voltage is desired. This method involves joining all the terminals of like polarity together. For instance, all the zinc terminal screws would be joined together by one wire, while all the carbon terminals would be joined by another conductor. A battery composed of cells in multiple connection would deliver a current having a voltage equal to that of one cell, but a current strength or amperage equal to that of one cell times the number of cells in the battery.

Q. Describe series multiple connection.

A. The system employed in joining dry cells in series multiple connection is clearly outlined at Fig. 90-B. Here three sets of four cells each which are coupled in series are joined together in multiple. By this method of connection, which is that generally used where the batteries are employed for ignition or lighting, one obtains the voltage of any one of the series combinations and the amperage of the three sets of cells. With a dry battery, having twelve cells coupled in the manner indicated, one will obtain a current having a pressure of six volts and a quantity of sixty amperes.

Q. What precaution is necessary when connecting dry cells together?

A. Care should be taken that the cells are well insulated from each other, and if carried in a metal box, suitable precautions should

be taken to insure against the battery containers coming in contact with the sides of the box. The terminals on the binding posts should be screwed down tightly in order to avoid loose connections, and the cells should be packed in such a way that they cannot shake loose when in service and break or loosen the connecting wires by vibration. Care should be taken when connecting cells in series that only terminals of unlike polarity be joined together and that the terminals of the same cell are never connected together in any way.

Q. What are the advantages of the dry cell?

A. The dry cell is simple, compact, economical and easily installed.

Q. What are the disadvantages of the dry cell?

A. The main disadvantages of a dry cell battery are that it is unsuitable for any except the lightest kind of intermittent service and that its capacity lessens as it is used. When the cells have deteriorated to a certain point, they must be thrown away and replaced by new ones.

Q. What is the standard size of dry cells?

A. The standard size of dry cell used for ignition purposes is 6 inches by 2½ inches and the cells are cylindrical in form. A larger size is sometimes used for stationary engine ignition that is about 3¼ inches in diameter and 8 inches high.

Q. What is the effect of size on battery capacity?

A. The greater the area of the plates or elements of the battery the higher its amperage or current output will be. The voltage, however, remains constant for cells composed of the same material regardless of size. For example, a dry battery no larger than a thimble having zinc and carbon elements and the conventional alkaline excitant, will have a pressure of 1.5 volts between the terminals, which is also true of a dry cell the size of a barrel. The amperage of the larger member would be directly proportional to the amount of surface of the zinc shell acted on by the electrolyte compared with that of the smaller member.

Q. What is a storage battery?

A. A storage battery such as outlined at Fig. 91 is composed of three secondary cells joined together and carried in a common

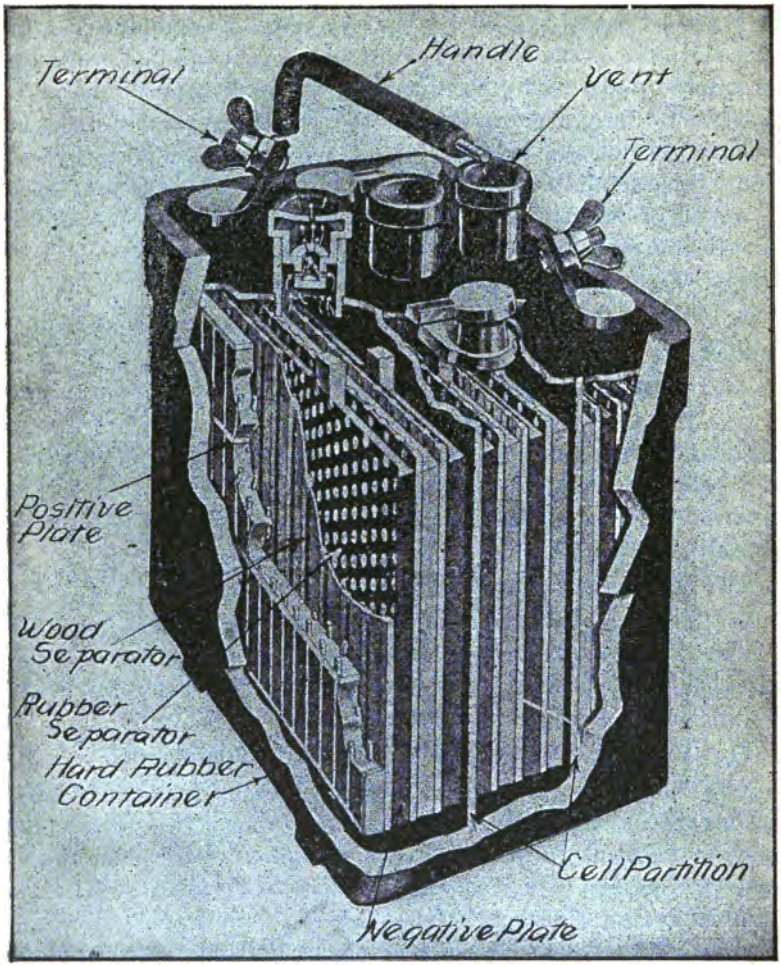


Fig. 91.—Sectional View of Geiszler Storage Battery for Ignition Service.

container jar of hard vulcanized rubber so they form a three cell combination that will deliver a current of about 6 volts and 60 amperes. A battery of this form is capable of being recharged when exhausted, as previously described.

Q. Name the principal parts of a typical storage battery.

A. The various units of which the storage battery is composed are clearly outlined at Fig. 92. The main container is separated into three compartments by partitions moulded integral with the jar and which divide the main container into three distinct parts. The plate assembly is composed of either four or five plates made of lead alloy grids filled with various lead oxides. The plates are separated from each other by thin sheets of hard rubber, perforated with many holes for the passage of the electrolyte and a ribbed wooden separator is interposed between each pair of plates. When a five plate assembly is used, three of these are positive or collecting members, and two are negative or generating members. A five plate assembly has greater capacity than a four plate form, because both sides of the negative elements are exposed to the corresponding faces of positive plates.

The plate assembly becomes a unit because the various members are joined together by a bus bar of lead burned to the lugs projecting from the plates by means of the hydrogen flame. The top of the individual compartments are then closed with hard rubber cell covers in which vents to permit of the escape of the gases without danger of losing the liquid electrolyte from splashing are screwed. The three cells are then covered by one large cover which has a soft rubber gasket interposed between the jar and cover as a packing. Other forms of storage batteries have a compound of pitch, rosin, and other elements directly over the cell covers to effectively seal the elements in their respective compartments. The disadvantage of this method is that it is difficult to remove the plate assembly for repairs or cleaning, whereas the separate cover, which is held in place by numerous small screws, can be readily removed when it is necessary to gain access to the interior of the battery.

Q. What determines the capacity of a storage battery?

A. The capacity of a storage battery depends upon the size and nature of the plates used in each cell and their number as well as the number of cells joined together to form a battery. Batteries ordinarily used for ignition purposes are either of the 6 volt, 60 ampere, or 6 volt, 80 ampere type. Those used for lighting service

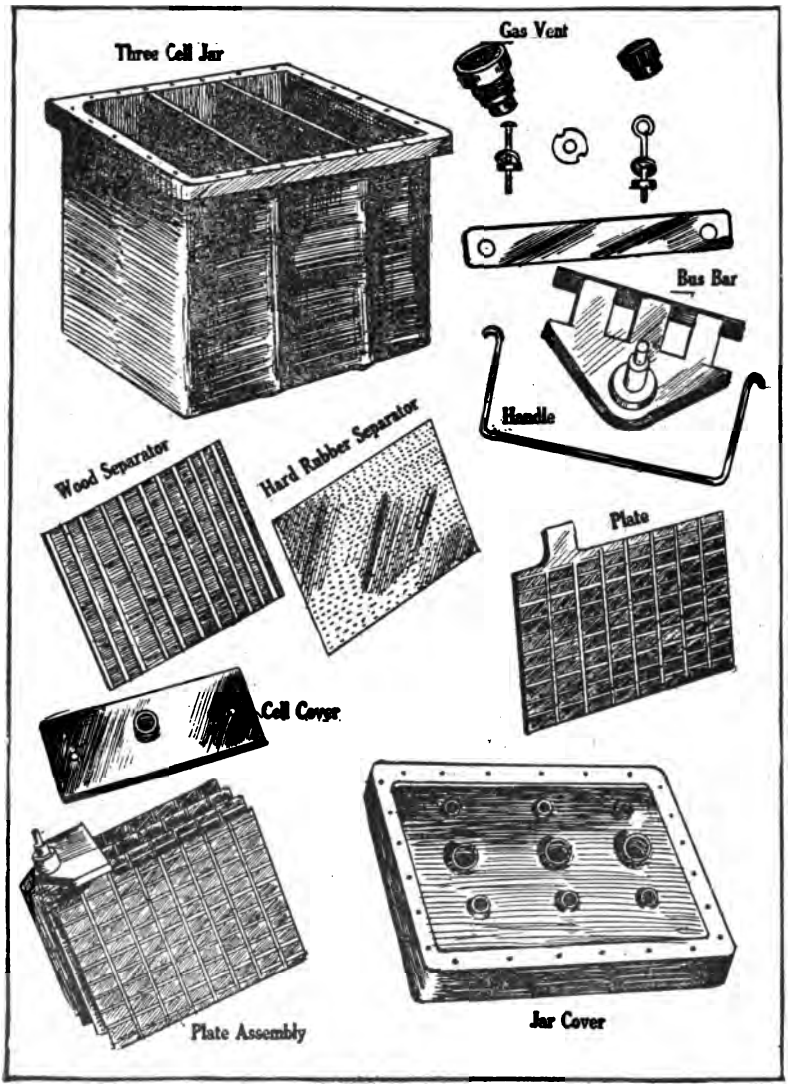


Fig. 92.—Parts of Typical Storage Battery Used for Ignition Purposes.

have larger plates and are more substantial in construction and are usually rated at 6 volts, 100 amperes and 6 volts, 120 amperes.

Q. What is meant by "discharge rate"?

A. A storage battery is designed so that it will deliver a certain amount of amperes over a given period of time. For instance, if the plates are light, the discharge of from 3 to 5 amperes should never be exceeded. This means that a 6 volt 60 ampere hour capacity battery would be able to discharge 3 amperes for 20 hours or 5 amperes for 12 hours before it would need recharging. The lighting batteries have much heavier plates and are constructed to stand larger discharge rates. In using a storage battery, it is imperative not to exceed the safe discharge rate given by the manufacturer.

Q. What would be the effect if the safe discharge rate was greatly exceeded?

A. If current was drawn from a battery faster than its discharge rate the battery plates will be injured and will buckle and this results in loosening the active material from the grids and causes accumulations of sediment or "mud" in the bottom of the cell jars which might short circuit the battery.

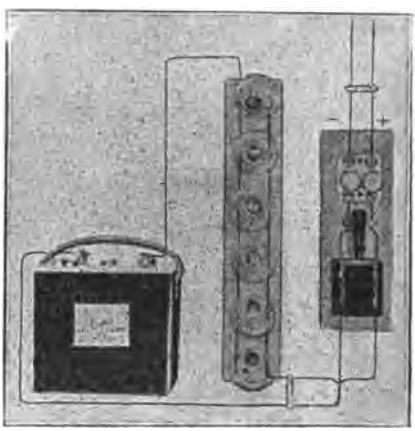


Fig. 93.—Diagram Outlining Method of Charging Storage Battery From Direct Current, Using Lamp Resistance.

Q. How are storage batteries treated when exhausted?

A. When storage batteries are exhausted they can only be restored to deliver more current by passing electrical energy through them from some external source.

Q. How are storage batteries charged from direct current?

A There are two methods of charging storage batteries from direct lighting circuits, one of which is outlined at Fig. 93, the other at Fig. 93-A. A storage battery should not be charged too fast because if attempt is made to rush the reforming of the plates by

passing large quantities of current through the cells, this will prove fully as disastrous as discharging the battery too rapidly. The manufacturers of various batteries recommend a certain normal charging rate, as well as a discharge rate.

A battery must a ways be charged longer than its rated capacity would indicate. For instance, if a charging rate of 5 amperes was recommended and a battery of 60 ampere hour capacity was to be restored to activity, it would take about 15 or 16 hours to charge it instead of the 12 hours one might think necessary if the total

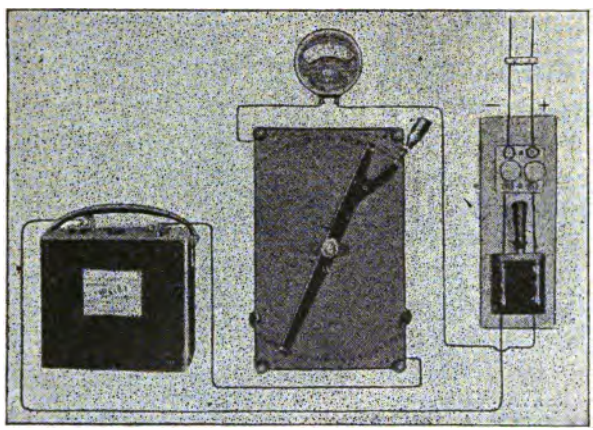


Fig. 93A.—Use of Rheostat Resistance Outlined When Charging Storage Battery From Direct Current.

capacity was divided by the charging rate. Storage batteries can be charged directly from 110 volt or 220 volt direct current lighting circuits by simply using a bank of lamps in series with the battery as indicated at Fig. 93 or a rheostat as shown at Fig. 93-A to regulate the number of amperes flowing into the battery. Then a bank of lamps is employed, either 16, 32 or 64 candle power bulbs may be utilized. A 16 candle power carbon filament lamp consumes about .5 of an ampere when used on 110 volt circuit. If it is desired to pass 3 amperes of current through the battery one can use six 16 candle power lamps in multiple or three 32 candle power; or one 64

and one 32 candle power bulb. When a rheostat is used an ammeter is interposed in the circuit in order to determine the amount of current flowing through the battery. The amperage can be regulated by varying the position of the rheostat control handle so that more or less resistance is interposed in the circuit.

Q. How are storage batteries charged from alternating current?

A. Storage batteries can be charged from alternating current only by using some form of rectifier in order that the alternating impulses will be made to flow through the battery in only one direction. These may be of the mercury bulb or electrolytic form, both types having been used with success.

Q. What is the electrolyte of the storage battery?

A. The electrolyte or exciting liquid used in a storage battery is a dilute solution of sulphuric acid and water, mixed to the proportion of about ten parts water to one part acid.

Q. What is its specific gravity when battery is fully charged, and how is this determined?

A. The specific gravity of the electrolyte forms a good indication of the condition of the storage battery. When fully charged, the specific gravity should be 1350 degrees when tested with the standard form of hydrometer, having suitable scale for use with storage battery electrolyte.

Q. How does a mechanical generator of electricity produce current?

A. The current of electricity obtained from a mechanical generator is derived by passing a number of loops of wire wound around a soft iron core between the pole pieces of a powerful magnet so these coils of wire cut the lines of magnetic force. This induces a current of electricity in them proportional to the speed at which they are rotated, the number and size of the coil loops and the strength of the magnetic energizing field.

Q. What is the difference between a dynamo and magneto?

A. A dynamo differs from a magneto principally in the manner of creating a magnetic field. In the dynamo electro-magnets are

used to excite the pole pieces between which the armature revolves, while in the magneto the field magnets are of the permanently excited type without any winding.

Q. Describe action of typical dynamo.

A. A typical dynamo is shown in section at Fig. 94. The principal parts are the armature, which revolves between the pole pieces, and the field magnet which surrounds the armature. A large number of windings of insulated wire are suitably disposed on the armature core and are connected to segments of a collecting device termed a "commutator," which is mounted on the armature shaft so that it turns with the armature. The shaft to which the armature and commutator are secured is mounted on ball bearings and is driven by

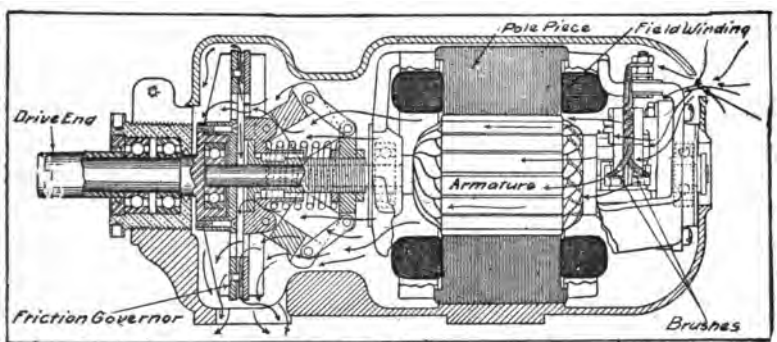


Fig. 94.—Sectional View of Typical Dynamo Generator Devised for Automobile Use.

a friction governor which prevents the armature from being driven at excessive speeds. The field magnets are composed of a number of stamped laminæ of soft iron around which are wound two coils of wire that serve to magnetize the field when a current of electricity is passed through them. As the armature is revolved between the pole pieces, the electrical current induced in the armature windings is delivered to the commutator, from which it is collected by brushes attached to terminals by which the device is joined to the external circuit. The entire assembly is housed in a metal case so it is completely protected.

Q. How many types of magneto are used?

A. Two main forms of magneto are used for motor car ignition

purposes. One of these generates a current of low voltage and is called a "low tension magneto," while the other form produces current of high potential and is called a "high tension magneto."

Q. Describe action of low tension device.

A. The low tension magneto has an armature winding composed of but one size of wire, and before the current will overcome the resistance of the air gap at the spark plug points it must be transformed to a higher voltage by means of an induction coil.

Q. How does high tension magneto differ in construction from low tension types?

A. There is no marked difference in general design of high and low tension magnetos. The difference is principally in the armature winding, which is a double form on the high tension device. A current of sufficiently high potential is delivered directly from the armature to the spark plug in the high tension system because the two windings give practically the same effect as is obtained from the ordinary form of induction coil.

Q. What are the advantages of the true high tension principle?

A. The high tension magneto has advantages that are readily perceived. Owing to the elimination of the induction coil and its auxiliary wiring it is a self contained device that is practically a complete ignition system in itself, needing only spark plugs in the cylinders and short wires connecting them to the distributor of the magneto to complete it.

Q. Wherein is a dynamo superior to a magneto?

A. A dynamo is superior to a magneto in all cases where currents of large amperage and constant value are needed, as in charging storage batteries or supplying current for electric lights and electric self-starting systems.

Q. Why is a magneto better for ignition?

A. A magneto is superior for ignition because on the efficient forms they will produce a current of sufficient intensity to explode the gas charge in the cylinders when turned at very low speed. The usual form of high tension magneto will produce a hot spark with but a quarter turn of the armature, which makes it possible to

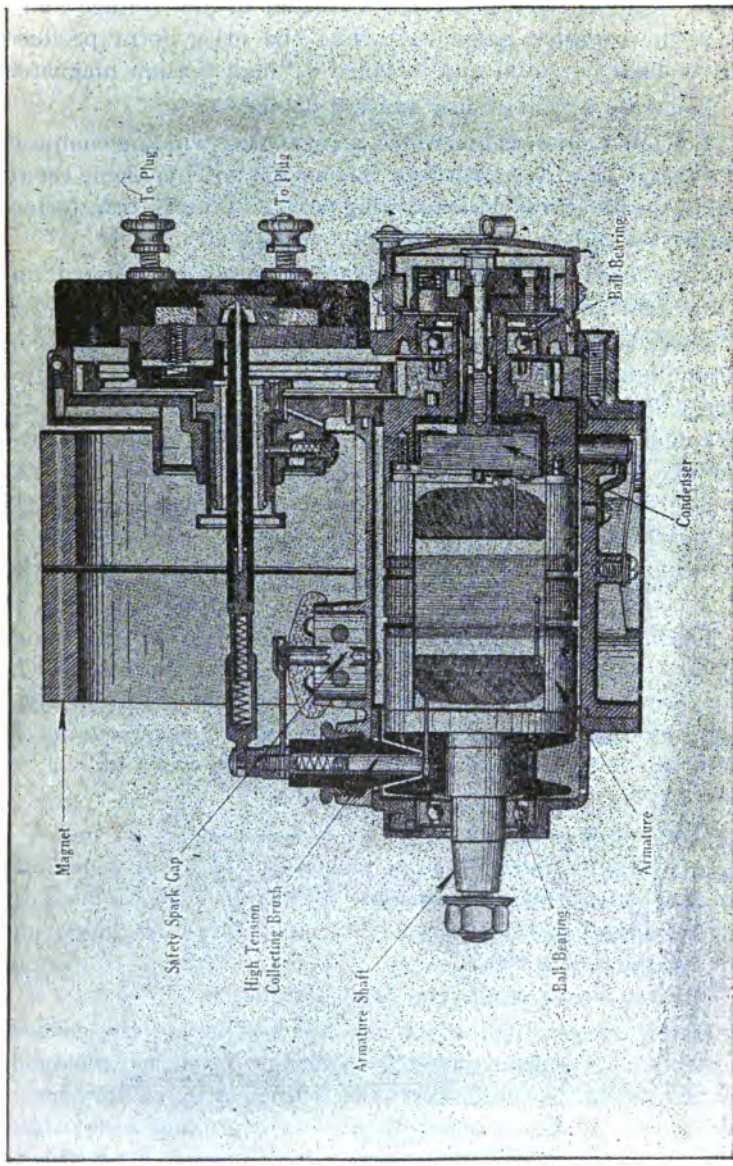


Fig. 95.—Longitudinal Cross Section of Bosch D. U. 4 High Tension Magneto.

start an engine equipped with a device of this character more easily than would be the case if a dynamo was employed. Owing to the use of permanent magnets the magnetic field is always present in a magneto, whereas it has to be built up in a dynamo and only attains its maximum value after the armature has made several hundred revolutions. Obviously, the magneto with its constant magnetic field will deliver current as soon as the armature is rotated enough to cut the lines of magnetic influence between the pole pieces.

Q. Name principal parts of high tension magneto.

A. The principal parts of a high tension magneto are clearly indicated at Fig. 95. The magnetic field is produced by two pairs of permanent magnets of the horse shoe form between the pole pieces of which the armature assembly revolves. The armature shaft is supported by ball bearings in order that it will turn with minimum friction. A condenser is mounted in the armature and revolves with it while a breaker box is carried at one end of the armature shaft. The current generated in the armature is collected by a brush that bears on an insulated ring carried by an ebonite insulating spool mounted on the driving end of the armature shaft. From the armature the current is delivered to the high tension distributor.

Q. How is the armature wound?

A. The method of winding the armature is clearly shown at Fig. 95 and 95-A. Two different sizes of wire are used, one being coarser than the other. The coarse wire is wound around the armature core to form a primary winding, while the fine wire is wound over the primary coil to form a secondary winding.

Q. What does the distributor do?

A. As is clearly shown at Fig. 95-A, the high tension current delivered from the secondary winding of the armature is collected by a carbon brush which conveys it to a central distributing segment in the distributor casing. Four contacts, which are insulated from each other and the rest of the magneto, are used on a four cylinder magneto and it is to these segments the various wires that run to the spark plugs are joined. The distributing brush conveys the high tension current from the central portion of the distributor

which revolves at one-half armature shaft speed to the various contact segments progressively and from these to the plugs in the cylinders in their firing order.

Q. What is the function of the breaker box?

A. The breaker box which is clearly shown at Fig. 96 makes and breaks the primary circuit twice each revolution, and for each interruption in the circuit, which is caused by the contact points separating because of cam action, a current of electricity is induced in the secondary winding. This, in turn, produces a spark at whichever plug happens to be in connection with the revolving distributor

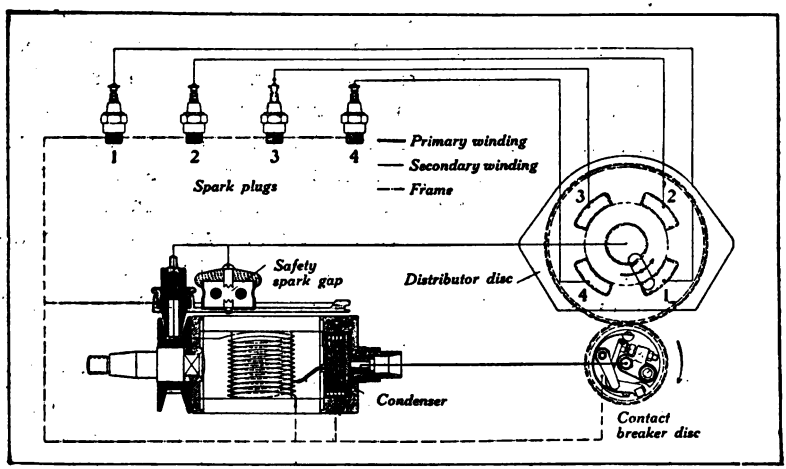


Fig. 95A.—Diagram Showing Wiring of Bosch D. U. 4 Magneto.

brush. The breaker box may be rocked back and forth, or oscillated to advance or retard the time of the spark.

Q. Why is a condenser used?

A. A condenser is used in a magneto for the same reason that it is incorporated in an induction coil and that is to absorb the excess current that would be apt to produce a spark between the platinum points of the contact breaker when they are separated.

Q. What is the purpose of the spark gap?

A. The spark gap is a simple device that corresponds to the

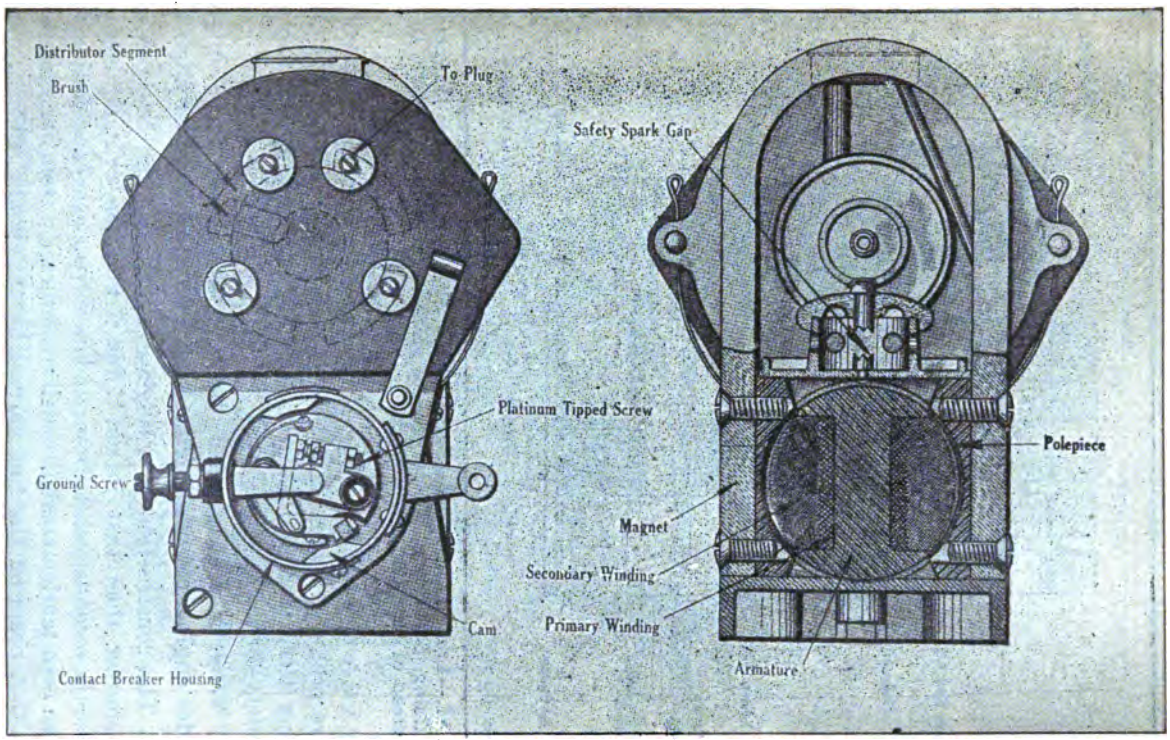


Fig. 96.—End View Showing Breaker Box and Sectional View Showing Armature and Safety Gap Construction of Bosch D. U. 4 Magneto.

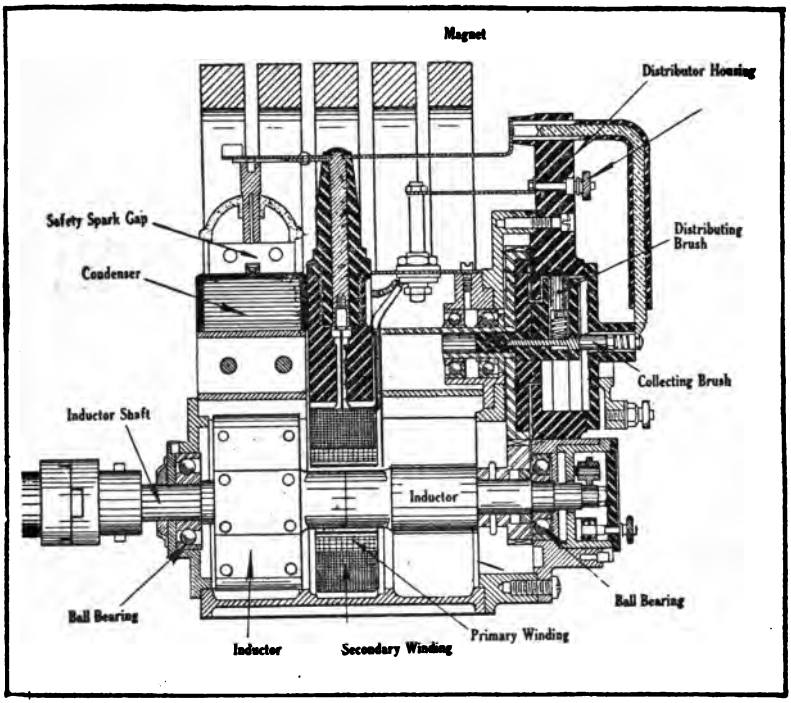


Fig. 97.—Longitudinal Cross Section of K. W. Four-Cylinder Magneto Using Stationary Windings and Rotary Inductor Members Instead of Revolving Windings.

safety valve of a steam boiler. If currents of sufficiently high voltage are produced by the armature to burn out or short circuit the winding it can escape to the ground by leaping across the air gap of the safety device.

Q. What is the difference between a magneto for a single cylinder engine and one intended for a multiple cylinder engine?

A. The construction of a single cylinder magneto is considerably simpler than that intended for a multiple cylinder engine because the secondary distributor and its driving gears are eliminated and the high tension current is delivered directly from the collector brush that bears on the ring carried by the ebonite, fiber or hard rubber spool on the armature shaft. A multiple cylinder magneto

will have a distributor to which the high tension current is delivered which in turn is commutated to the various segments which deliver the current to the spark plug. The contact breaker of a one cylinder magneto employs a single point cam, whereas that of a multiple cylinder employs a two point cam.

Q. How fast are magnetos driven on two- and four-cycle engines?

A. The armature speeds are just twice as fast as the following values for a two-cycle engine having the same number of cylinders as the four-cycle types that follow. A single cylinder magneto turns at camshaft speed, a two cylinder magneto will be driven at either camshaft or crankshaft speed depending upon the arrangement of the contact breaker box and whether or not it is fitted with a distributor. A magneto intended for a three cylinder engine is driven

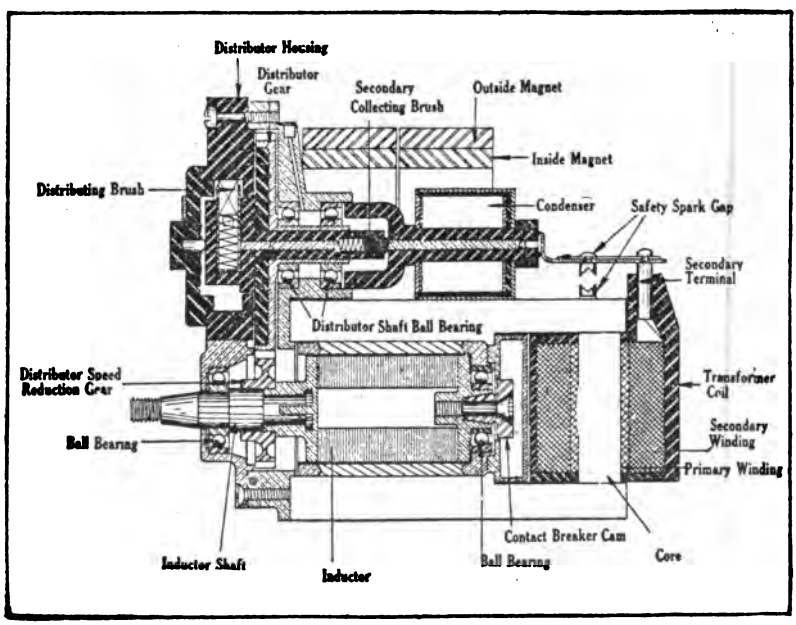


Fig. 98.—Longitudinal Cross Section of Pittsfield Magneto, Another Form Utilizing a Rotating Inductor and Stationary Transformer Coil.

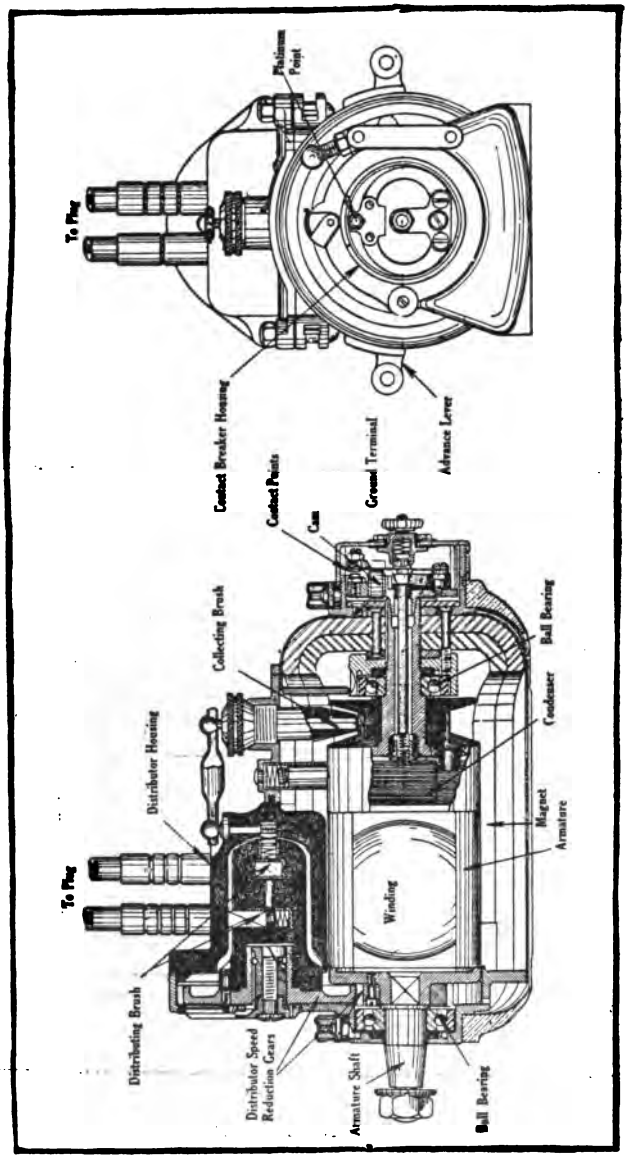


Fig. 99.—Longitudinal Cross Section and End View of Mea Magneto Which Employs Bell-Shaped Magnets and in Which the Spark is Advanced by Displacing Magnetic Field by Rocking the Magnets.

at three-quarters the speed of the crankshaft, while a four cylinder device is driven at the same speed as the crankshaft. Owing to the greater frequency in explosions in a six cylinder motor, it is necessary to turn the magneto armature at 1.5 times the crankshaft speed.

Q. How are distributor contacts spaced?

A. The contact segments in a secondary distributor are spaced just the same as those of a primary timer when used on the same type of engine.

Q. Why must magneto speed and distributor arrangement be changed for the different number of cylinders?

A. As the number of cylinders are increased the number of explosions needed each revolution of the crankshaft augments proportionately, so it is necessary to drive the magneto faster because a spark is obtained but twice each revolution of the magneto armature. On a four cylinder engine, which has two explosions per revolution of the crankshaft, the magneto armature is driven at the same speed as the crankshaft, because it is capable of supplying a spark each half revolution of the armature. On a six cylinder engine where the crankshaft receives three power impulses per revolution it is necessary to drive the magneto at a speed that will enable it to deliver three sparks for each revolution of the crankshaft, which means that the magneto armature must turn half again as fast as the motor shaft. Obviously, the distributor contacts must be changed in number on each size of magneto because one contact segment is used for each cylinder to be fired.

Q. How are magnetos driven?

A. Magnetos of the high tension type used for ignition purposes are always positively driven by chain or gear connections with the engine crankshaft or camshaft.

Q. Why are positive driving means essential?

A. The magneto armature must be driven positively because the current generation must be timed to occur at the proper time for ignition in the engine cylinders and this makes it imperative that the drive be by some non-yielding positive means in order to

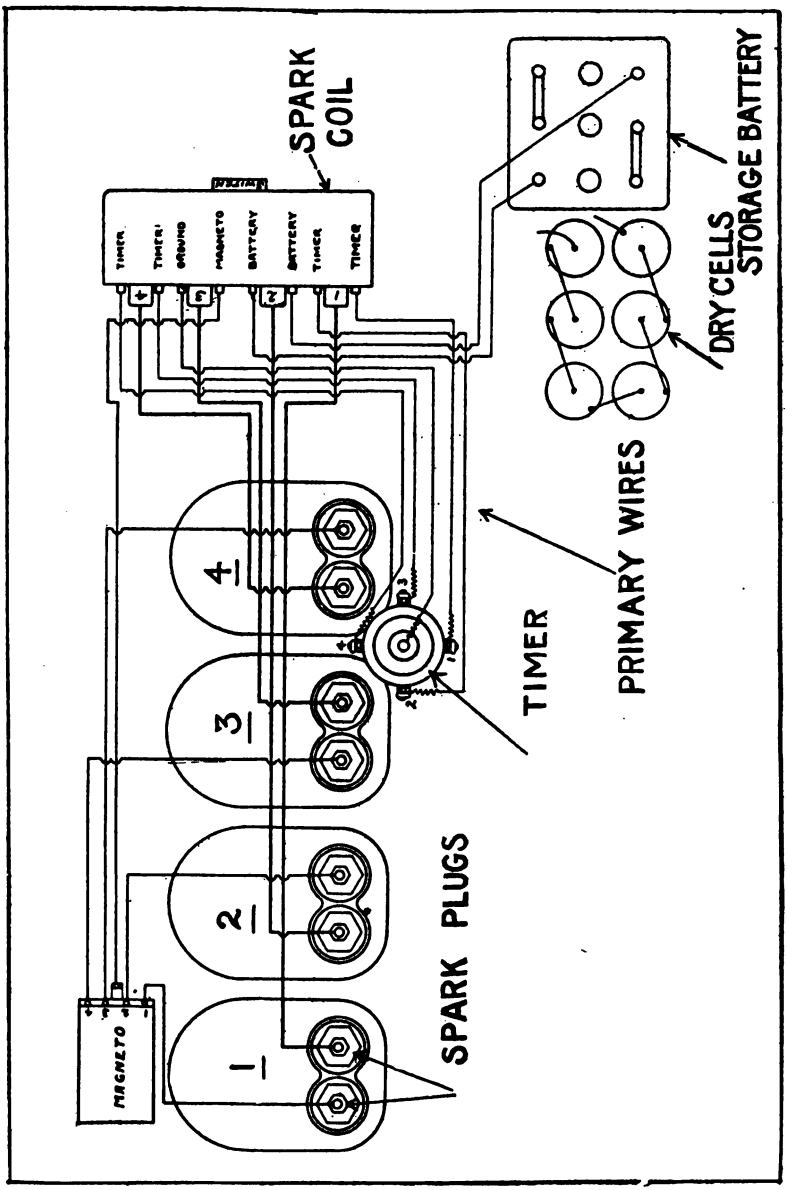


Fig. 100.—Double Ignition System, Comprising Two Independent Groups, One Deriving Current From Batteries, the Other From a High Tension Magneto.

insure that the ignition spark will always occur at the same time relative to the piston position or at top center in the cylinder about to be fired.

Q. How are dynamos driven?

A. Dynamos may be driven by direct gearing, if desired, though this is not necessary because this instrument delivers a low tension current that must be used in connection with suitable timing and intensifying means that are auxiliaries to the dynamo. A dynamo can be driven by flat or V leather belts and in some forms the armature is rotated by contact of a friction pulley against the engine flywheel periphery.

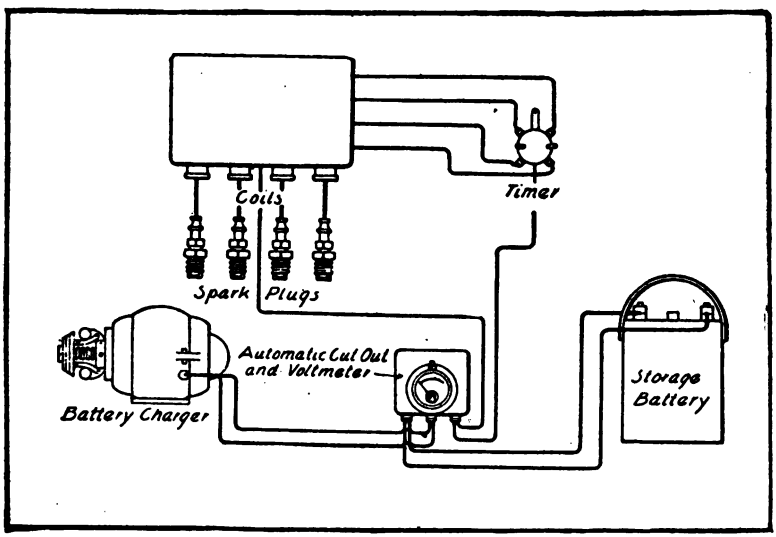


Fig. 100A.—Outlining Method of "Floating Battery on Line" Generally Used When Current From Dynamo Type Generator is Employed for Ignition, Electric Lighting or Self-Starter Service.

Q. Describe a combination battery-magneto ignition system?

A. On some forms of engines two practically separate ignition systems are provided, one being by battery, timer and spark coil, while the other system is by magneto, which is another self-contained system. When used in the manner outlined at Fig. 100, either magneto or battery outfit may be utilized for ignition pur-

poses. The change from one to the other is easily accomplished by shifting a switch lever. When a system of this kind is provided the battery group is intended to be used only for starting and emergency service in event of failure of the mechanical generator. The magneto is used regularly in order to conserve the battery energy. Combination systems of this nature are seldom provided at the present time because the improvements made in magneto design and construction have practically eliminated all liability of trouble at this point. Many cars made in previous years are fitted with combination systems so it is well for the reader to become familiar with the arrangement of the parts and their functions.

Q. What is meant by "floating the battery on the line"?

A. A storage battery is said to be "floated on the line" when it is used in connection with a dynamo which keeps it always fully charged as outlined at Fig. 100-A. The dynamo current is first directed to an automatic cut-out arrangement and from thence to the storage battery, the cut-out being used to interrupt the circuit when the dynamo is not generating energy in order to prevent the storage battery from discharging back through the dynamo and converting that into a motor. The current for ignition is taken from the storage battery instead of from the dynamo so that a constant delivery of current is obtained regardless of fluctuations in engine speeds and the changing amounts of current delivered from the battery charger because of these variations in rotative speed of the dynamo armature. When utilized in this manner a storage battery gives very good service, because it is always kept fully charged by the dynamo and is operating at maximum efficiency. This system can be applied to great advantage in connection with electric car lighting and engine starting systems.

LESSON TEN

LOW TENSION IGNITION SYSTEMS

Q. Name principal parts of low tension ignition system.

A. A low tension ignition system consists essentially of the current generator usually of the magneto form and a series of make-and-break contact plates attached to the cylinder wall in such a way that a pair of contact points extend through into the combustion chamber.

Q. How is the spark produced in the cylinder?

A. The spark is produced in the cylinder by the separation of the contact points at the instant of maximum current generation in the magneto armature.

Q. How is the spark timed?

A. The make-and-break igniter plates are operated by a camshaft, as outlined at Fig. 101, and the points of the igniter plate are only separated by the mechanism at the time a spark is desired in the combustion chamber. The spark time is thus controlled by the position of the operating cam which is usually so timed in relation to the crankshaft travel that it will separate the igniter points in the cylinder about to fire at just the proper time.

Q. Is battery current strong enough to produce low tension spark?

A. Battery current can be utilized in producing a low tension spark though more energy is required than would be needed by a high tension ignition system. The battery current must be intensified to some extent by means of a "kick-coil" which increases the current value at the time contact is broken in the engine cylinder. Dry cells are not suitable for use on low tension igniter plates unless these have been designed especially for use with battery current.

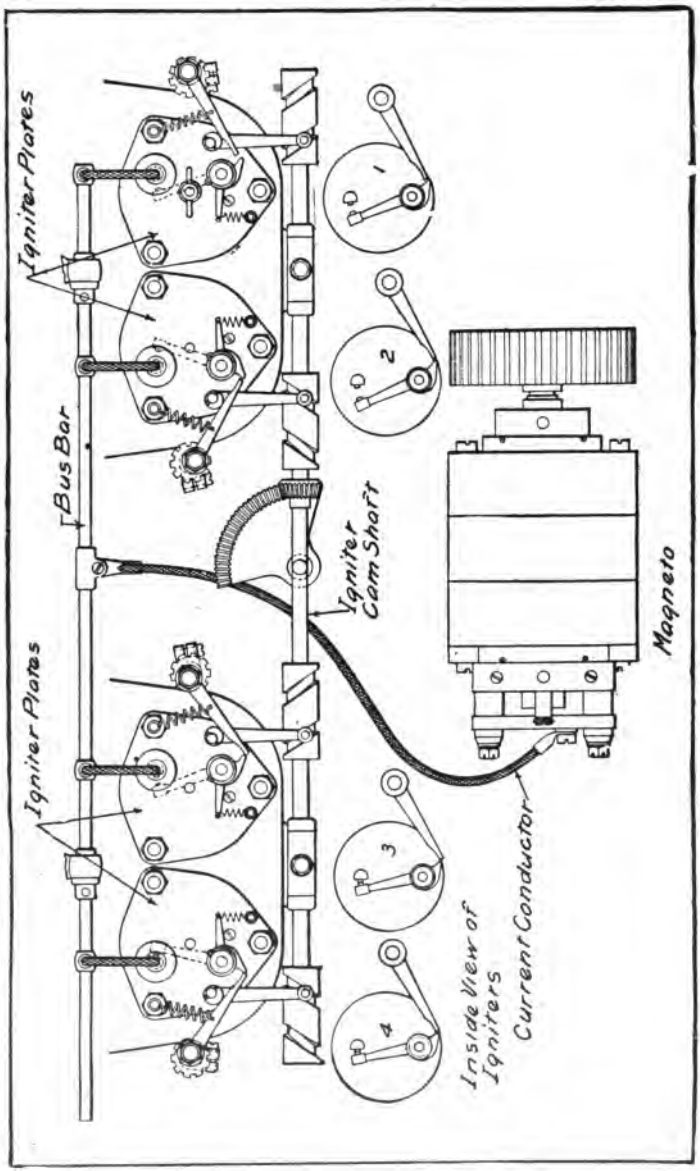


Fig. 101.—Outlining Operation of Low Tension or Make and Break Spark Plates for Four-Cylinder Ignition Systems.

A storage battery is more suitable because it will maintain a steadier flow of current and is not exhausted so soon as primary cells, especially if the igniter plate construction is based on the use of electrical current supplied by a magneto. An igniter plate intended for use solely with batteries is devised in such a way that contact is established and broken between the points of the igniter plate only when a spark is necessary, whereas on igniter plates that operate with magneto current the points are kept permanently short-circuited or in contact together until the spark is needed in the cylinder. Where the contact points are practically always together it will be seen that the battery current would be permanently short circuited. Therefore, on most forms of low tension ignition systems the battery is supplied only for an emergency use, as it will soon become exhausted if employed for regular ignition service.

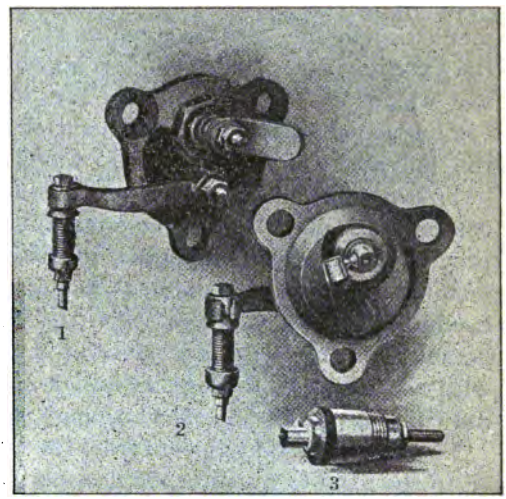


Fig. 102.—Low Tension Igniter Plate Used on Locomobile Cars.

Q. How is spark coil made, and what is the difference between low tension "kick coil" and induction coil used in high tension systems?

A. The kick coil consists of a core of soft iron wire around which is wrapped eight or ten windings of coarse magnet wire No. 16 or 18 gauge. Unlike the induction coil the "kick coil" has only one winding of coarse wire and does not employ a vibrator or condenser. It is much simpler than the induction coil, because the secondary winding, the condenser and the vibrator parts are eliminated. It is connected in series with the battery current, i. e. the positive

wire which leads to the bus bar or to the insulated terminals of the igniter plate is connected to one of the terminals of the coil so the winding of the coil really forms an extension of the conductor leading to the igniter plates. The other battery terminal is connected to the ground through a simple form of switch.

Q. Describe construction of igniter plate.

A. A typical igniter plate which has been used successfully on many Locomobile cars is shown at Fig. 102. The view at 1 shows the exterior of the plate which is approximately triangular in form and which has three projecting lugs by which it is bolted to the combustion chamber. The interior view is shown at *2*, this showing the movable hammer member, which is rocked by the simple lever extending to the tappet rod operated by the camshaft. The combination of hammer and operating lever forms a bell-crank provided with a suitable journal in the igniter plate so the hammer member can rock back and forth and establish contact with the fixed insulated member which is called the "anvil" and which is shown detached from the igniter plate at *3*. The hammer is provided with a platinum contact point which normally rests against a similar contact member on the stationary anvil.

The wire conveying current from the magneto or battery is attached to the fixed terminal or anvil insulated from the main body portion of the igniter plate. The plate shown is provided with a taper joint, so that it makes a gas tight connection when inserted into the opening made to receive it in the combustion chamber wall.

The method of operation of the igniter plate is clearly outlined at Fig. 103-A. As will be seen the cam lifts the roller on the tappet rod plunger and establishes the circuit which is broken as soon as the roller rides off of the point of the cam and the contact points at the gniter plate are separated.

In the diagram at Fig. 103-B the various parts of the igniter plate operating mechanism are clearly outlined. The main current conveyer or bus bar *1* is brought into electrical connection with the insulated terminal *6* and the anvil carried in plate *3* by means of the switch lever *2*. The grounded hammer member *4* is operated by the external lever *5* which establishes contact between the hammer *4* and the anvil *6* when it is raised by the rod *9* which applies

its pressure through the medium of the spring *8* as the roll carrying plunger *11* is raised by the cam member in the guide bushing *10*. When the roller carrier *11* drops off the point of the cam, the rod *9* is pulled down and the hammer *4* is separated from the anvil *6* by means of the nut *7* at the end of the rod *9*. The spark time is advanced and retarded by sliding the igniter operating camshaft along so that the roller on the member *11* is raised sooner or later depending upon its position with reference to the inclined cam point.

Q. Is coil needed with magneto on low tension ignition system?

A. As the magneto armature may be wound with sufficient

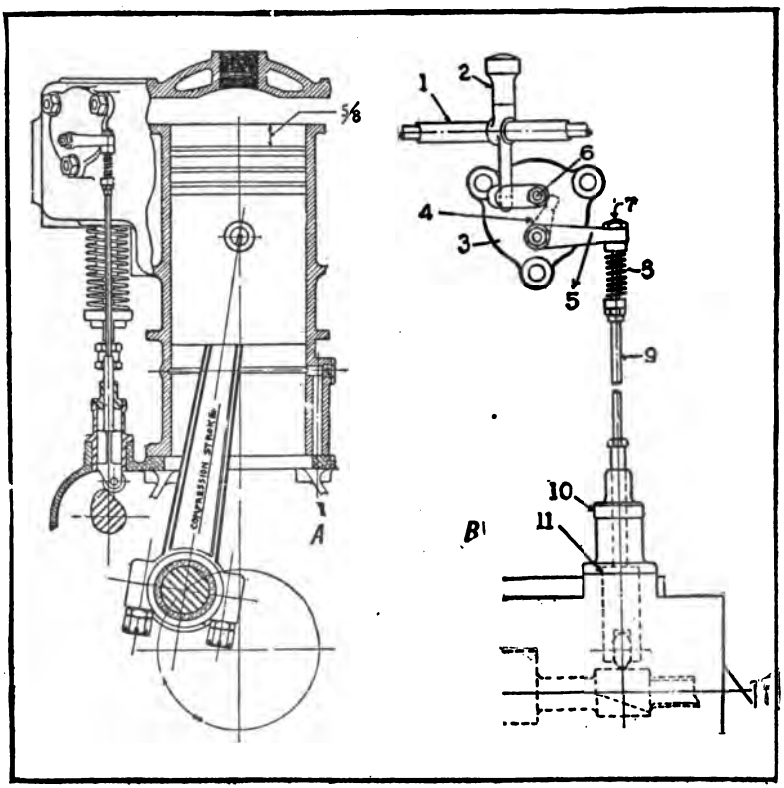


Fig. 103.—Showing Action of Locomobile Low Tension Igniter Plate.

wire to produce a hot energetic spark a current of sufficient intensity may be produced directly from the mechanical generator without the use of a "kick-coil" such as necessary with a battery.

Q. Must magneto be timed?

A. The armature of the magneto must be timed with a certain definite relation to the crankshaft of the motor because the igniter points separate in the combustion chamber only when the magneto armature has attained that portion of a revolution where the current generation in the armature winding is at its maximum value. This means that the magneto must be driven by positive means from the engine crankshaft, and on a four cylinder engine the magneto armature runs at crankshaft speed just as in the high tension forms.

Q. What are the advantages of this system?

A. It is claimed that the low tension system of ignition is not affected by water as is the high tension form with exposed spark plugs and that it will produce a hotter spark than will the high tension system. It is widely used in marine and stationary installations but is seldom employed at the present time on motors intended as automobile power plants.

LESSON ELEVEN

HIGH TENSION IGNITION SYSTEMS

Q. How many types of high tension ignition systems are used?

A. Two main forms of high tension systems are used, those in which the current is generated by a magneto and the others which use chemical current producers to generate the electrical energy which must be intensified by means of transformer coil before it can be directed to the plugs.

Q. Describe action of simple induction coil, timer, and battery system for single cylinder engines.

A. The arrangement of the parts of a simple, high tension ignition system has been previously considered and is clearly outlined at Fig. 77-A. The current is supplied by means of a storage battery or a six cell dry battery, as desired. The positive terminal of the dry battery group and that of the storage battery are joined together and are connected with the ground which may be any point on the metal frame of the engine. The wire from the zinc terminal of the dry battery group goes to one side of a two point switch while the negative terminal of the storage battery is connected to the other side of the switch. Either the dry or storage battery may be brought in circuit with the induction coil and timer by moving the switch lever to one side or the other.

The timer is a simple form having one insulated contact segment which is connected to one of the primary terminals of the coil. The other primary terminal of the coil is connected to the switch lever while the secondary coil terminal is connected to the insulated terminal of the spark plug by means of a well insulated high tension cable. As the crankshaft of the engine revolves, it turns the revolving contact member of the timer and when the piston reaches

the proper position in the combustion chamber the roll on the revolving timer member makes a contact with the insulated segment carried by the timer case. Assuming that the switch lever is on the storage battery contact button, the current will flow from the positive terminal of the storage battery to the ground on the engine base and from thence through the medium of the metal parts of the engine to the revolving timer brush, which is in metallic contact with the engine camshaft, and which, therefore, transmits the current through the insulated segment to the primary terminal of the spark coil, because of the connection or wire joining these two parts.

When the current passes through the primary winding of the coil it produces a secondary current in the high tension winding as has been previously explained and passes out of the coil box through the primary terminal which is joined to the switch lever and from that point back to the storage battery through the switch lever and the wire connecting the battery with the switch. As long as the engine revolves a contact will be established at the timer every two revolutions of the crankshaft and a current will flow from the batteries through the primary winding of the coil and back again to the battery. Each time a primary circuit is established at the timer a spark will be produced at the spark plug points and the gas compressed in the combustion chamber by piston will be exploded.

Q. Outline action of induction coil, timer, and battery system for four cylinder engine.

A. The action of the four cylinder ignition system outlined at Fig. 100 is exactly the same as that previously described. Instead of a single unit coil a spark coil assembly having four units, one for each cylinder, is employed and a timer is used that has four insulated contact segments, one for each cylinder of the engine. As the timer contact revolves it makes an electrical connection with the various insulated segments in turn so that the various primary windings are energized when a spark is desired in the cylinder that is to be fired, depending upon the firing order. In the group shown at Fig. 100, a spark takes place first in cylinder No. 1, then in cylinder

No. 2, followed by a spark in cylinder No. 4 and lastly one in cylinder No. 3.

Q. Describe action of distributor system.

A. It is not necessary to use a separate unit for each cylinder to be fired as single induction coil may be used for any number of cylinders, if a combined primary timer and secondary distributor is employed. A distributor system for a six cylinder engine is clearly shown at Fig. 104. The batteries are connected to the switch which is mounted on the face of the spark coil in the customary manner and the connection between the switch lever and the primary winding is made in the regular way, only that the wire does not show because the connect on is made inside of the coil box. The primary timer is just the same as the form used in all battery ignition systems except that the six insulated primary contact segments are joined together by a metal band outside of the body and a single wire leads from these to the primary terminal at the top of the coil, which is exactly the same type as used on a single cylinder engine.

The secondary terminal of the coil is connected to the rotating distributing brush carried at the upper portion of the distributor. This secondary brush establishes contact with the various terminals, which are joined to the spark plugs in the cylinders. The wires are arranged in such a manner that the spark plugs are brought into action progressively as the firing order dictates. The primary timer portion establishes six contacts every revolution and all of these energize the one primary winding. The distributor brush is depended on to do the timing and to convey the high tension current from the spark coil to the plug where the spark is to occur.

Q. What are the advantages of the distributor system?

A. When a separate induction coil unit is used for each cylinder it is difficult to adjust the vibrators on all of the coil units so that they will be exactly the same in adjustment and it is possible for one or more of the vibrators to lag behind the others, i. e. they will not start to vibrate as quickly as those which may differ in adjustment and as a result the spark does not occur at absolutely the same time relative to the piston position in all the cylinders. When a single coil is used on a multiple cylinder engine but one vibrator

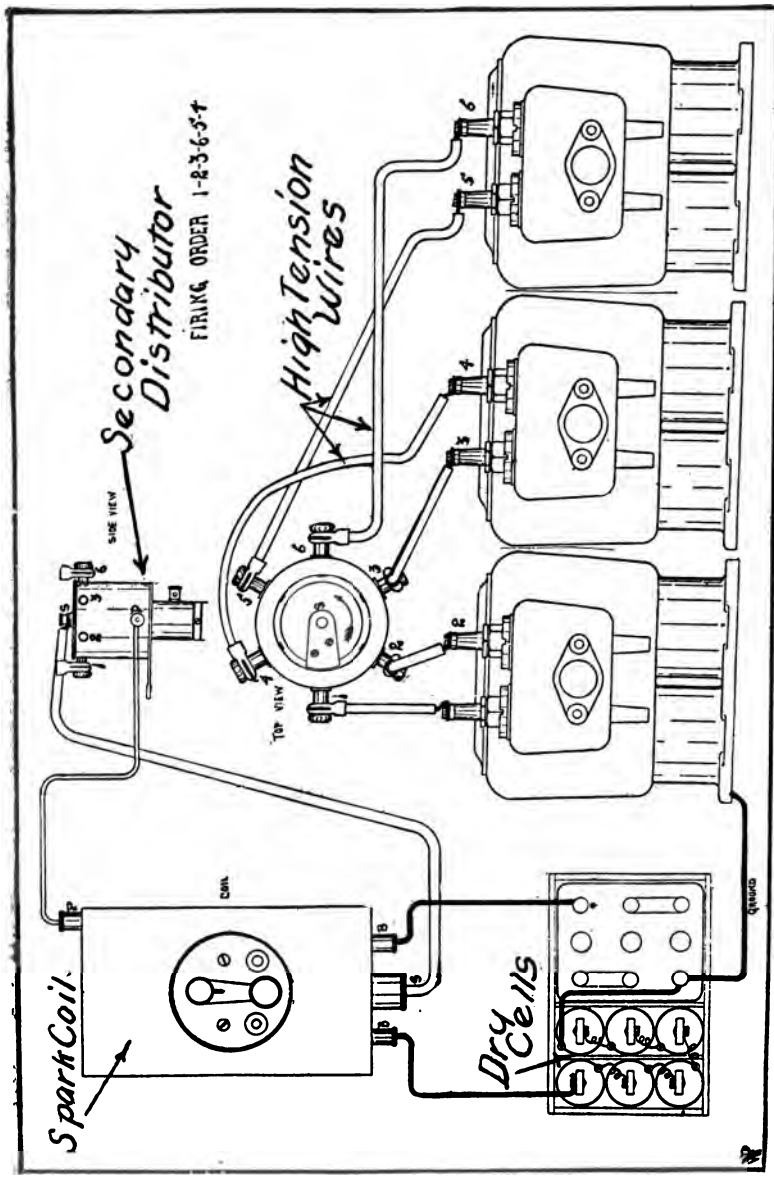


Fig. 104.—Typical High Tension Battery Ignition System With Secondary Distributor for Six-Cylinder Engine.

is provided and its adjustment is the same for all cylinders. As the one vibrator is depended on it will be kept in constant motion and less primary current will be needed to energize the primary windings.

A properly installed secondary distributor is the simplest method of obtaining synchronized ignition with battery and coil system. The use of a single coil greatly simplifies the system, especially on four and six cylinder engines where the multiple unit coil is large and occupies considerable room. The electrical wiring is simplified and the liability of trouble owing to short circuited wires, loose connections, etc., reduced because less wire is needed

Q. What is the "master vibrator system"?

A. A master vibrator system is similar to the conventional multiple unit coil ignition method, the only exception being that a specially constructed vibrator is used for all four units of the coil. It is wired in circuit with the various coil units and operates regardless of which contact is made at the primary timer. With a master vibrator the advantage offered by the distributor system of only having one vibrator for any number of cylinders is obtained, but the wiring is not simplified and practically all the parts used in the conventional multiple unit coil system are used with the addition of the master vibrator. A master vibrator coil will consume more current than the regular multiple vibrator coil or a single coil used with a distributor.

Q. Describe simple true high tension magneto system.

A. The essential parts of a high tension magneto ignition system are outlined in diagram form at Fig. 95-A and it will be seen that the wiring is very simple and not liable to give trouble. In this diagram the armature is shown in part section so that the various components and the methods of connecting them together can be readily ascertained. When the device is actually in use there are but five external wires. Four of those are heavily insulated and extend from the terminals on the magneto distributor to the spark plugs in the cylinder. The remaining wire is joined to the ground and can be interrupted when desired by a switch. Unlike a battery ignition system, the ground wire circuit is completed when it is

desired to interrupt the magneto action and the switch is opened when the magneto is to supply current.

The internal wiring is not difficult to follow. One end of the primary winding is attached to the condenser case while the other is joined to the ground. The same wire that joins the condenser to the primary coil is attached to one of the leads of the secondary winding. The other end of the secondary winding goes to the col-

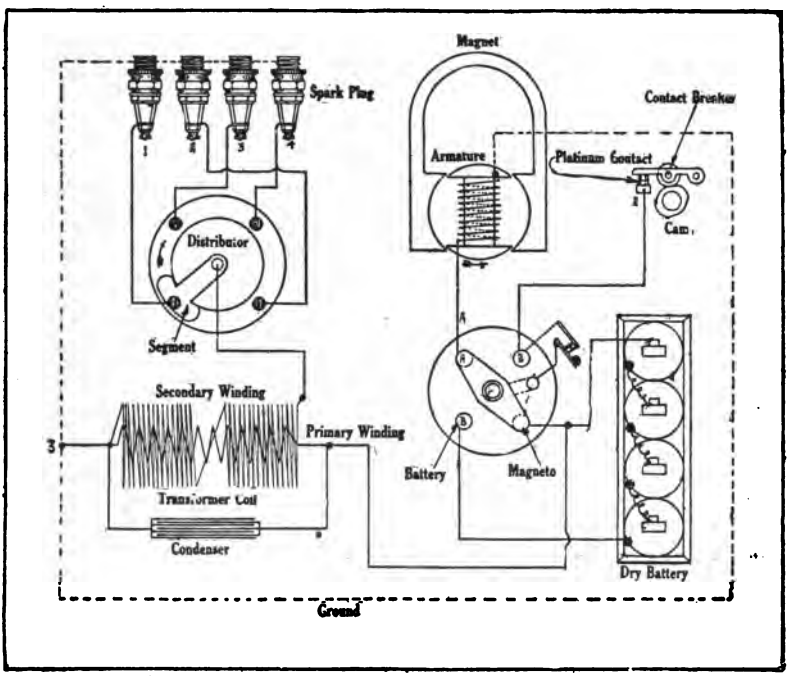


Fig. 105.—Explaining Wiring of Splitdorf Transformer Coil Magneto System.

lector ring carried by the insulating spool on the magneto armature shaft and from thence the current is collected by a carbon brush and delivered to the revolving portion of the secondary distributor. The primary wire attached to the condenser case extends through and is in electrical connection with the insulated contact point in the contact breaker. The other contact lever is

grounded. The condenser casing is made in two parts, one of these being in metallic contact with the ground while the other which is insulated from it serves to convey the primary current to the breaker box.

As the armature revolves, the contact breaker points separate when the bell crank is rocked by the actuating cam rolls and each time that this break occurs, this being timed so that it is simultaneous with the position of maximum current generation of the armature, a spark takes place at whichever spark plug the distributor arm (which is also timed in relation to armature travel) happens to deliver the current to. As will be evident the true high tension magneto system is very simple when compared to battery and coil ignition systems that do not give as hot a spark and that are not nearly as reliable.

Q. Outline transformer coil magneto system.

A. The wiring arrangement of a transformer coil ignition system using magneto current is clearly shown at Fig. 105, the various parts being separated in order to make the action clear. As is true of the simpler high tension system the spark plugs are connected to terminals on a distributor and the high tension current is delivered to the central revolving member of the magneto distributor. Instead of the derived current being taken directly from the magneto armature it is passed through the primary winding of an induction coil which is similar in action and construction to the form used with batteries except that it has no vibrator. One end of the primary winding is grounded while the other goes to the magneto terminal of the switch and from thence through the magneto armature from which it flows back again to the ground through the medium o the magneto contact breaker.

When the armature is in the position of maximum current generation, the platinum points of the contact breaker are separated by the cam and the primary current must rush through the primary winding of the coil before it reaches the ground instead of having a short circuit to the ground through the contact points of the contact breaker, as is possible when these are together. The rush of current through the primary winding induces a secondary current

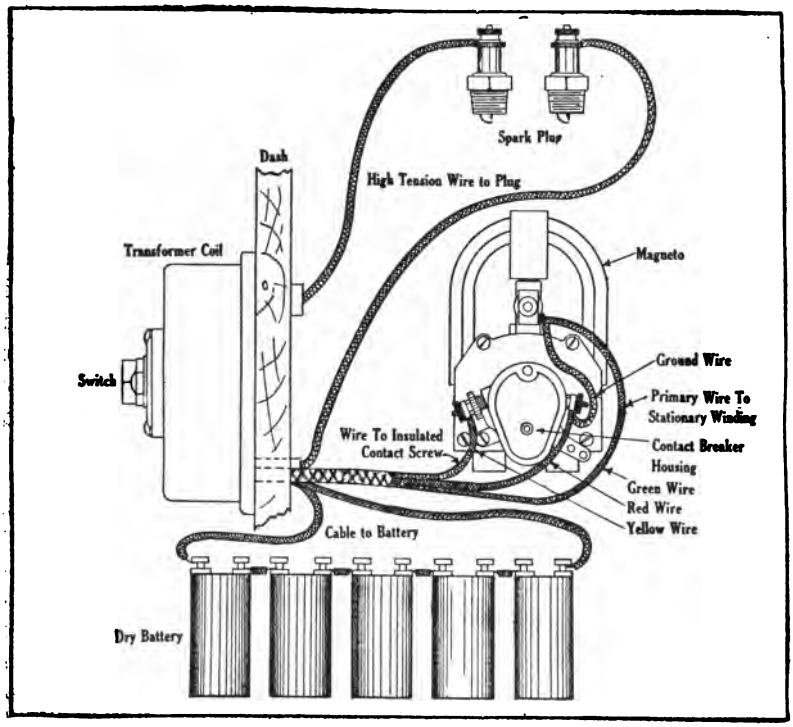


Fig. 106.—Diagram Showing Wiring of Remy Magneto System for Two Cylinder Motor.

in the winding of fine wire having sufficient voltage to overcome the air gap between the points of the spark plug.

If the switch lever is turned from the position indicated so it is in contact with buttons No. 2 and *B*, the battery current from a set of dry cells is used to energize the primary winding, the contact breaker of the magneto serving to interrupt the battery current and the distributor serving the same purpose whether the primary current is derived from the magneto armature winding or from the battery. The external wiring of two systems of this kind is outlined at Figs. 106 and 107. The former is for a two cylinder engine, while that at Fig. 107 is the wiring plan of the same elements shown at Fig. 105.

Q. Is the spark coil always a separate unit?

A. The spark coil used with a magneto-transformer system is always a separate unit from the armature winding but it is sometimes incorporated as part of the magneto, being carried under the arch of the magneto as in the Connecticut device or at the rear end of the magneto as in the Pittsfield construction.

Q. Describe action of double ignition system using one set of plugs.

A. Sometimes when two distinct ignition means are fitted and the magneto distributor and contact breaker are the timing parts of each system it is possible to utilize but one set of spark plugs instead of the two sets which are necessary in double ignition systems of the form outlined at Fig. 100. The diagram of the wiring of a double ignition system using one set of plugs is clearly outlined at Figs. 108 and 109. The arrangement is always such that either a separate

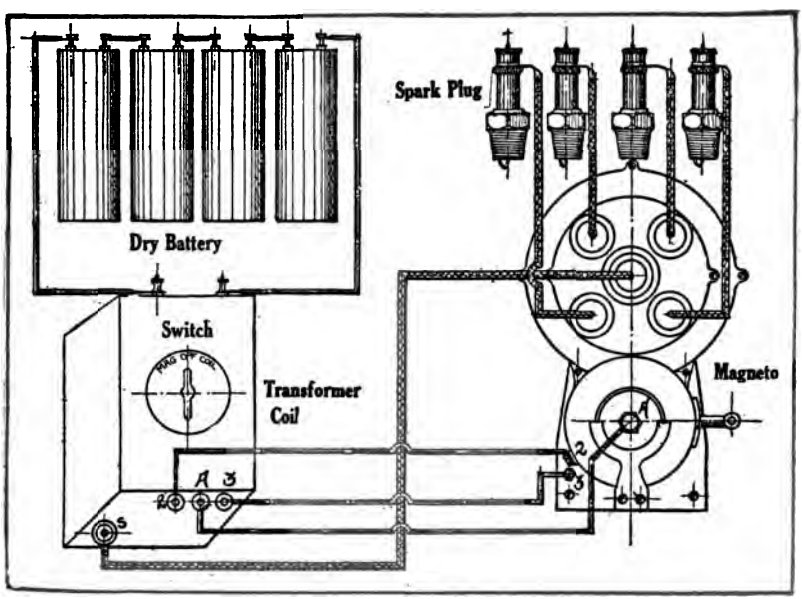


Fig. 107.—Diagram of Wiring of Splitdorf Low Tension Transformer Coil System for Four Cylinder Ignition.

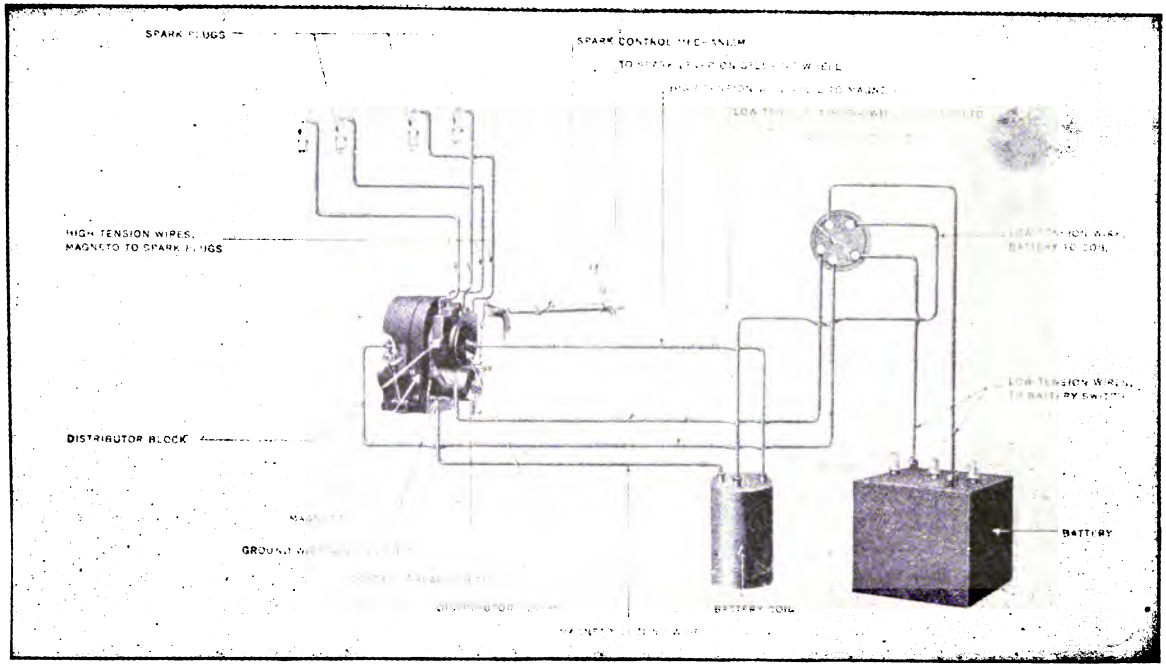


Fig. 108.—Ignition System Used on Chalmers Cars Employs Battery and Magneto as Source of Current and One Distributor for Secondary Current Supply to One Set of Spark Plugs.

battery contact maker is incorporated as an auxiliary to the usual form of magneto contact breaker or the magneto contact breaker itself serves to interrupt the primary current from the battery as well as that from the armature winding. In the system shown at Fig. 109 the battery contact maker is carried at the lower portion of

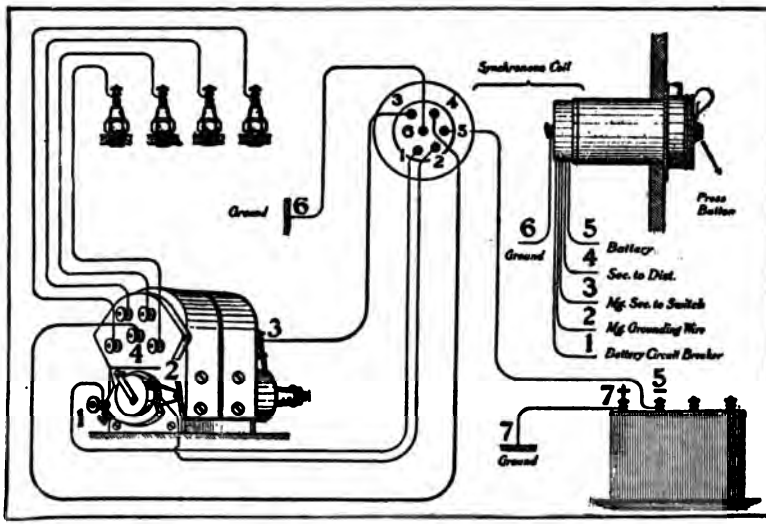


Fig. 109.—Wiring Diagram of Bosch Dual System Using One Set of Plugs.

the magneto breaker box. The induction coil is combined with a switch and is a form that can be easily secured to the dash of the car. The greater portion of the coil box extends through the dash and the connections as they are made can be clearly followed by reference to the diagram.

Q. What is the "Unisparker" system?

A. This is a secondary distributor system in which a non-vibrator coil is employed in connection with a form of timer having platinum points that establishes instantaneous contact and sends just one impulse through the primary winding of the induction coil instead of a series of impulses as produced by the ordinary roller contact timer and vibrator. It is contended that the one impulse

will generate a strong enough spark to explode any charge of gas the cylinder may contain and that the short contact is very economical of battery energy because it does not require as long a period of discharge as do the roller contact forms of timers, and there is a greater period of time between the battery discharges to permit the cells to recuperate, which is an important factor when primary current generators of the dry cell type are employed. This system is not as extensively used at the present time as it has been in the past owing to rapid strides made by the magneto in popular favor.

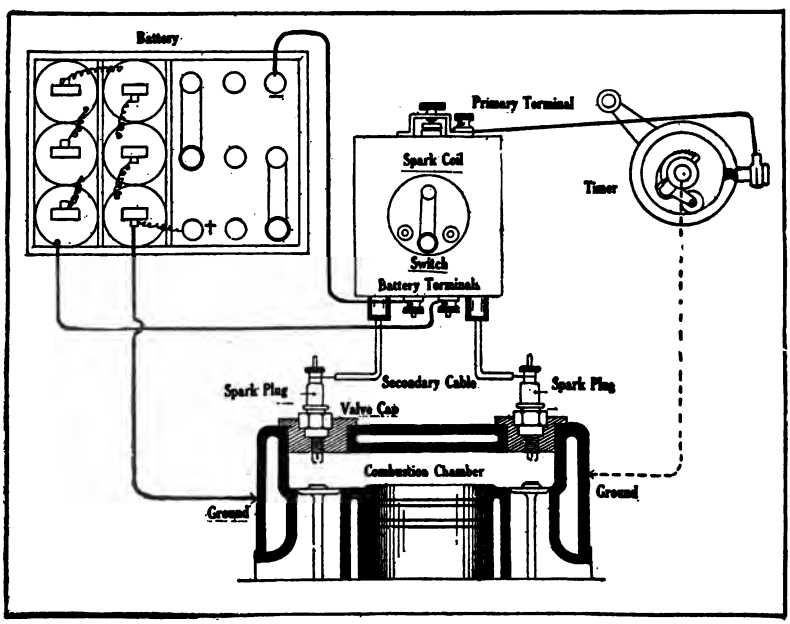


Fig. 110.—Two-Point Ignition System for One-Cylinder Engine.

Q. What is two-point ignition?

A. Two-point ignition systems are those in which two sparks are made to occur simultaneously at separate points in the combustion chamber. A typical two-point ignition system intended for a one cylinder engine is clearly outlined at Fig 110. As will be seen one spark plug is carried over each valve of a T head engine cylinder. The coil used has two secondary terminals instead of

having one of the secondary leads grounded as is common practice. One secondary terminal goes to the insulated terminal of one spark plug while the other is joined in a similar manner to the other member. The primary winding is just the same as employed for the usual form of induction coil. Every time the contact is established at the timer and the spark coil brought into action the secondary current is forced to leap two gaps instead of one and a spark is produced at each plug at practically the same instant.

Q. What are the advantages of this method?

A. On engines of the T head form which have large combustion chambers it is claimed that the two point ignition system will result in more energetic ignition because combustion is more rapid due to the compressed charge having been fired at two different points. The advantages of this system are not apparent at low or moderate engine speeds but at high speeds it is claimed that a 20% increase of power is obtained over the single spark ignition system.

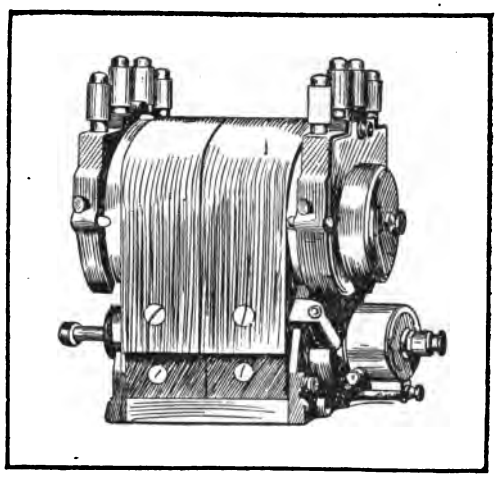


Fig. 111.—Double Distributor Magneto, Utilized for Two-Point Ignition System.

Q. What special apparatus is needed for two point ignition?

A. Either the spark coil or the spark plugs must differ from conventional construction in order to obtain two point ignition. If spark plugs of the conventional type are used as shown at Fig. 110 the induction coil must have two secondary terminals for each unit and the secondary current cannot be grounded, as is the conventional practice. If the regular form of spark coil is used having a grounded secondary terminal it is necessary to employ a special form of spark plug in connection with one of a regular pattern in

each cylinder. A special two-point plug having two insulated electrodes passing through the insulating member must be used instead of the conventional pattern and this is introduced in the secondary circuit so that it is in series with the spark plug of the regular pattern used in conjunction with it. The spark must jump the gap at the two point plug before it can reach the gap between the electrodes of the regular pattern plug.

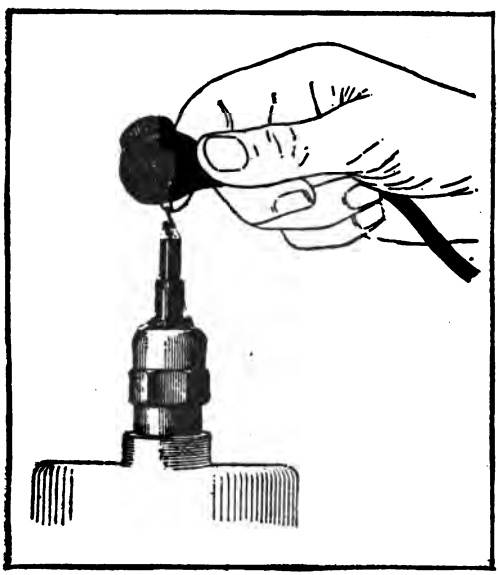


Fig. 112.—Showing Utility of Insulated Terminal to Test Current Flow to Spark Plugs.

Q. Can two point ignition be obtained when magnetos are used?

A. A special form of magneto is necessary to obtain two-point ignition and use magneto current. A device of this kind is illustrated at Fig. 111 and it differs from the conventional construction, inasmuch as it has two secondary distributors and practically two separate windings on the magneto armature if it is a true high tension type. If used in connection with a transformer coil system a four terminal coil will be needed instead of the usual form and each of the secondary leads connected to its respective distributor. One contact breaker serves both distributors on either the true high tension or transformer coil forms.

Q. How can current flow to plugs be tested with magneto system?

A. The current delivery to the ignition plugs can be easily ascertained when a magneto is used by an insulated terminal such as

outlined at Fig. 112. When it is suspected that a plug is not firing it is possible to remove the terminal from the plug without danger of electrical shock and then by holding the terminal away from the plug electrode an eighth of an inch it is possible to see the current jump the air gap and thus determine if the electricity reaches the spark plug. If a spark jumps between the terminals and the plugs and the cylinder does not fire it s reasonable to assume that the plug is dirty and that the trouble is not with the magneto. If no spark jumps between the terminal and the plug it indicates either a broken or grounded wire or a defective contact at the distributor.

LESSON TWELVE

METHODS OF LUBRICATING THE AUTOMOBILE POWER PLANT

Q. What is lubrication?

A. Lubrication consists of interposing between two surfaces that have relatively great friction, a cushioning and almost frictionless medium that will separate these surfaces and enable the parts to move with expenditure of less power.

Q. Why is lubrication necessary?

A. If the moving parts of machines which work on or by each other and which are in frictional contact were not separated by a film of lubricating oil or grease the metallic contact would result in abrading the surfaces and producing rapid depreciation. In some parts enough friction might exist to cause the pieces in contact to become so hot that they would seize together. This would be very liable to occur in high speed bearings or in bearings subjected to heavy pressure.

Q. What is friction?

A. Friction is the retarding force that tends to prevent movement of all mechanism which is in motion. The friction may result from internal or external forces and it is exerted in such a way as to bring all moving parts to rest. Friction is generally caused by the interlocking of minute projecting particles which extend from the surfaces of all substances regardless of their nature or the accuracy of surface finish. Friction is greater between soft materials than it is between hard substances and the rougher the surfaces in contact the greater will be the amount of friction between them. It requires power to overcome friction in all cases and the greater the amount of friction present the more power is needed to overcome it.

Q. Should friction be eliminated in all parts of automobiles?

A. Some parts of motor cars perform work where friction is necessary to enable them to function properly while other parts will work more efficiently as the amount of friction is reduced. For instance, it is necessary to have friction between the parts of the clutch used to transmit power from the engine to the gearset and it is necessary to have friction between the brakes and the brake drums when these members are applied to stop motion of the car. If there was no friction between the tires of the driving wheels or traction members and the ground it would be impossible for the power plant to propel the car. At the other hand if there was too much friction at the bearing points of the motor, gearset, power transmission parts and wheels, it would be practically impossible to propel the car without using large quantities of power. It is important that friction be eliminated or reduced to as low a point as possible at all bearing points in order to obtain efficient power generation and transmission. The more friction there is in clutches and brakes he more efficient these members are.

Q. Name the principal lubricants and their derivation.

A. The principal lubricating mediums commonly used to separate the parts of machinery in motion are fluid oils and semi-fluid and solid greases derived from mineral and animal sources. Solids, such as graphite, which is a form of amorphous carbon, are also used for lubricating purposes.

Q. Are all lubricants suitable for the same parts?

A. The lubricating mediums best adapted differ with the nature of the work the parts are to perform. An oil that is suitable for one portion of the automobile mechanism may prove actually injurious to other parts.

Q. Name the conditions where oil can be used?

A. Oils are the only lubricants that can be successfully employed in lubricating automobile power plants. Oil is necessary wherever the amount of space for the film of lubricant is small or where considerable heat is present.

Q. Name conditions where only greases can be utilized.

A. In certain parts of the power transmission system such as in

the differential gears and driving gearing at the rear axle it is imperative that only semi-fluid greases be used, because the rear construction as ordinarily built is not oil-tight and would not retain fluid lubricants. The more viscous or heavy bodied greases are also necessary in sliding gear transmissions and gear driving systems, because oil would not have sufficient cushioning properties and would soon be forced from between the working surfaces of the gear teeth. Greases reduce noise and wear where pressures are heavy, while oils are better adapted on rapidly moving, close fitting parts.

Q. What are the best lubricants for automobile use and why?

A. Automobile lubricants should be derived from a crude petroleum base because oils of this nature are inorganic and are not apt to decompose by exposure to the air or by heat as are the organic lubricants derived from animal fats or vegetable sources.

Q. What is the most difficult part of the automobile to oil properly?

A. The cylinders of the automobile power plant are the most difficult portions to lubricate satisfactorily on account of the heat generated and great care is necessary in selecting oils for this purpose.

Q. What kind of lubricant should be used in the cylinder?

A. Gas engine cylinder oil should have sufficient body to maintain a positive film between the piston and cylinder walls and yet should not be so heavy that it will gum up the piston rings. It should have a high fire test which means that it should not decompose readily by heat and it should have a good cold test in order that it will not thicken too much at low temperatures. Its viscosity should be such that it will flow readily through pipes and so it can be pumped without difficulty by the various forms of gear and plunger pumps used to circulate oil. It should be free from acid and should be a pure mineral oil without adulterants or animal or vegetable fillers. It should be thoroughly filtered to remove the free carbon and other impurities which would be deposited in the combustion chamber when the oil is vaporized by the intense heat of the explosion.

Q. How can a lubricant be tested for acid?

A. A simple test for acid in oil can be made by dissolving a small quantity of the lubricant in alcohol which may be slightly warmed by immersing the test tube or flask in which the alcohol is contained in warm water. This will facilitate dissolving the lubricant, especially if heavy greases are tested. When the oil has been dissolved the solution may be tested with litmus paper which may be procured at any drug store. A piece of blue litmus paper will turn red when placed in the solution if any acid is present.

Another test which requires more time but which gives positive results can be made by soaking several strands of candle wicking or waste in the suspected lubricant and then wrapping these around a brightly polished steel shaft, placing this in the direct sunlight but not exposed to the elements. If pronounced etching or rusty spots are present under the strands of oil soaked material on the steel after the shaft has been exposed a few days it may be inferred that the oil contains acid and is not suitable for use on machines.

Q. What is the effect of acid in oil?

A. The presence of acid in oil is not desired because this will produce rusting or etching of the brightly finished bearing surfaces and will roughen them so they have considerable friction. Oils that contain acid are much quicker to act injuriously when used in the cylinder because they are rapidly decomposed by the heat present at that point. Obviously, rusty, roughened surfaces will have more friction than smooth, bright, well-polished ones.

Q. What is viscosity and how is it determined?

A. Viscosity is a term used in speaking of the body of oils and is measured by allowing a given quantity of the oil to be tested to escape from a container, a drop at a time. When two oils are compared for viscosity the one that flows from the container quickest is the most fluid, and therefore has less viscosity than one of heavier body which cannot flow as fast. In some parts of automobiles it is necessary that oils have considerable body, these points being where shock and heavy pressures exist, as in gear boxes and axles. Tight fitting bearings that should be free running usually require thinner oils on account of the small space existing between the journals and the brasses.

Q. What is flash test and how is it made?

A. The flash test is an indication of the amount of heating an oil will stand before the vapors given off will flash or catch fire. The method of performing the simple test is outlined at Fig. 113. A quantity of the oil to be tested is placed in a porcelain casserole which is heated by a Bunsen burner placed under the oil container which is carried on a tripod. A thermometer is placed in the oil to indicate the rise in temperature and when the vapors rising from

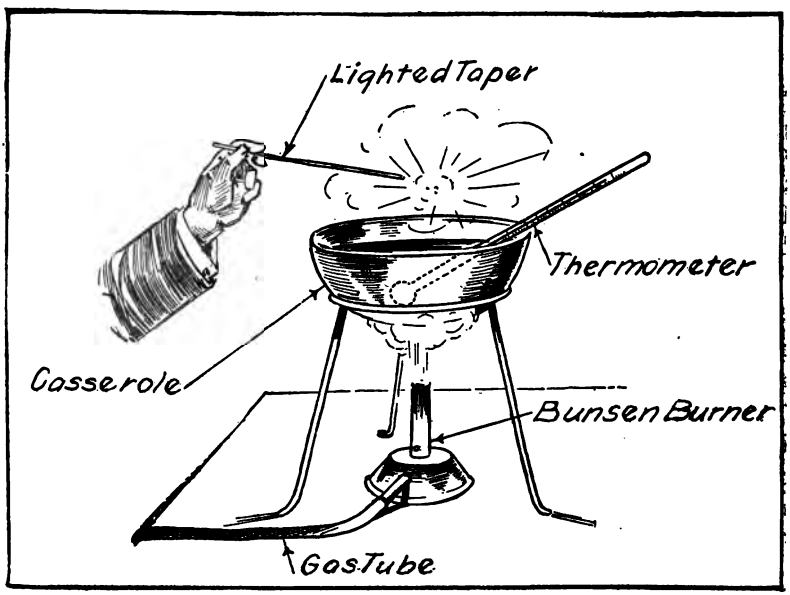


Fig. 113.—Defining Method of Testing Cylinder Oil for Flashing Point.

the surface can be flashed by a lighted wax taper the reading on the thermometer will indicate the flash point. In this connection it will be well to state that the thermometer is a special form which will indicate temperatures up to 650 degrees F. The bulb should be supported so that it will be kept from contact with the sides or bottom of the dish which are somewhat hotter than the oil and which would give a false reading. The flashpoint is made chiefly in connection with tests of cylinder oils, and it is desirable that these have

as high a flashpoint as possible so that they will not be vaporized from the cylinder walls as soon as they come in contact with the hot products of combustion.

Q. How is the fire test made?

A. The fire test of the oil is really a continuation of the flash test and is shown at Fig. 114. The fire test is the point indicated by the thermometer where the oil becomes sufficiently heated so not only the vapors flash momentarily but the entire mass of oil takes fire.

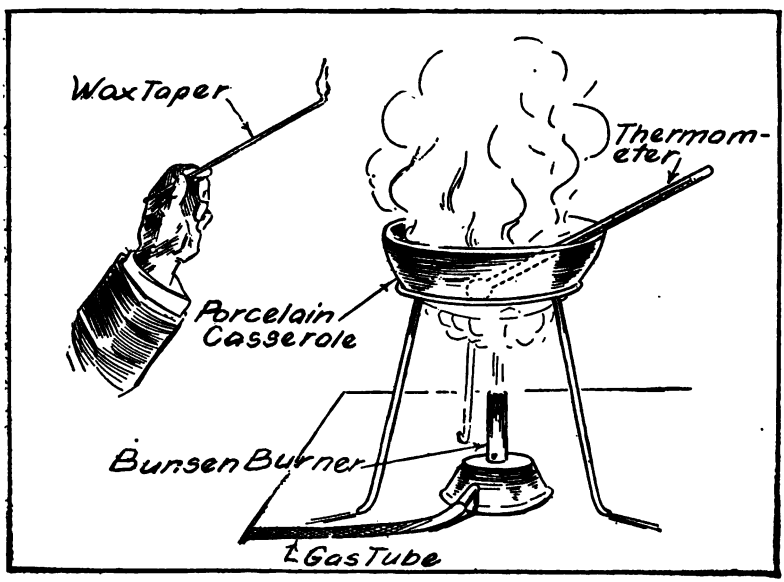


Fig. 114.—Simple Method of Making Fire Test of Lubricating Oil.

Q. What is the cold test and what does it indicate?

A. The cold test is made as indicated at Fig. 115 and is useful in showing the point at which oil will coagulate or become so stiff that it will not flow. This is easily performed by putting a flask of lubricant in a freezing mixture of ice and salt and inserting a thermometer to indicate the point at which the oil becomes solidified. An ordinary form of temperature indicating thermometer may be used in making this test. A suitable oil for winter use should

not stiffen enough at zero temperature to prevent its reaching the bearing points.

Q. Name simple ways to determine presence of adulterants.

A. The presence of animal fats in greases can be quickly determined by exposing a quantity of the suspected grease to the air. If the grease turns rancid and has a foul smell this may be considered a good indication that organic adulterants are present. The presence of fats in oils may be determined by the saponification test which consists of heating a quantity of lubricant under suspicion with potash and stirring briskly till the alkali is well absorbed by the oil. If the surface of the oil is covered with soapy matter after cooling it indicates the presence of animal fats in quantities proportionate to the amount of soap. In any mixed oil in which mineral and animal lubricants are combined, there is considerable fat which will decompose liberating fatty acid if used in the cylinder and there is also the danger of charring the fat and augmenting the proportion of carbon deposits in the combustion chamber.

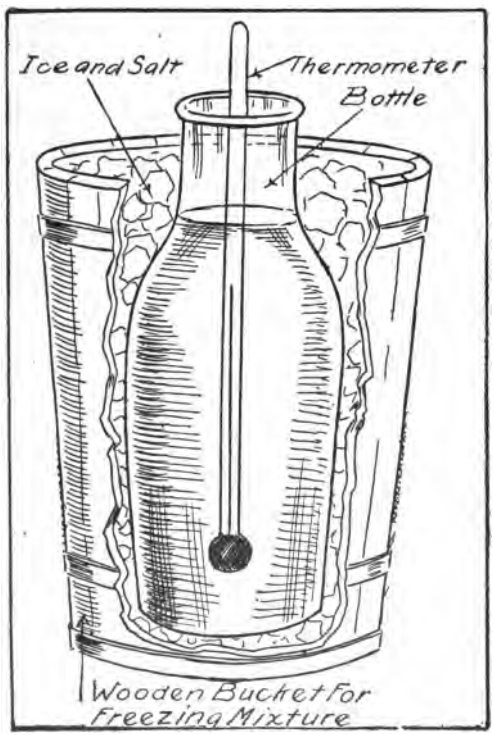


Fig. 115.—How Lubricating Oils May be Tested to Determine Temperature at Which Oil Will Solidify.

Q. What are specifications of a suitable cylinder oil?

A. The oils used for cylinder lubrication should preferably be

distilled in a vacuum in order that the light distillates, such as the fuel oils, will be separated from the crude petroleum base obtained from Pennsylvania wells at low temperatures and then filtering the oil through charcoal to remove free carbon and other impurities it contains. The greater the number of times the oil is filtered the lighter it becomes in color and body. The best cylinder oils are obtained in three grades: light, which has a consistency slightly greater than machine oil; medium, which is somewhat heavier than the light and is an intermediate grade between that and the heavy bodied oil which has the consistency of warm molasses. The light and medium oils are used on power plants having closely fitting pistons and bearings, while the heavy lubricants are used in air cooled engines and in power plants that have become worn to such an extent that the cushioning properties of the heavier bodied oils are desirable. Any pure hydro-carbon oil, having a high degree of viscosity at 100 degrees F., having a vaporizing point of about 200 degrees F., a flash point between 425 and 500 degrees F., and a fire test of 600 degrees F. or over, will be suitable for use in gas engine cylinders.

Q. How are the various portions of an automobile lubricated?

A. The power plant of an automobile is usually lubricated by some means that will insure a continued supply of lubricant to the interior parts of the engine and that will supply the oil in quantities that will compensate for any loss through vaporizing or burning in the combustion chamber or leakage. The change speed gear-set, differential gearing, universal joints and axle bearings are generally packed with a semi-fluid grease that remains in place and that does not need renewing frequently. Spring shackles, brake rod ends, and similar parts are greased by compression grease cups, which may be screwed up from time to time to inject more lubricant between the bearing surfaces or by means of small oil cups which demand periodical attention and filling from the usual form of hand oil can or syringe.

Q. Describe simplest method of oiling gas engine parts.

A. The interior of gasoline engines of the closed base form may be oiled by putting in a certain quantity of lubricant in the engine base

until it rises to such a height that it will be splashed around the inside of the motor by the revolving connecting rod lower end or by counter weights or enclosed flywheel. On open base engines (never used in automobiles) the main bearings are lubricated by compression grease cups in many cases and the connecting rod by oil from a small sight feed oil cup directly attached to the crank pin bearing. A similar member of larger capacity serves to oil the piston and cylinder walls. The open base form of motor is never used in automobile practice though it has received wide application in the stationary power plants and is used to some extent in marine service.

Q. What is a sight feed lubricator?

A. The gravity sight feed lubricator is seldom used at the present time in automobiles. The first sight feed devices included a container for the lubricant having glass walls, so the amount of oil it held could be readily ascertained at any time, communicating with a lower chamber, also having glass walls, by means of a needle valve controlled orifice. The valve could be adjusted to feed any desired number of drops of oil per minute and the flow of oil could be stopped at will without changing the adjustment of the needle valve by shifting a small lever that allowed the valve to drop under slight spring pressure until it closed the passageway communicating to the small sight feed chamber beneath the main container which was piped to the point needing the lubricant. As a general rule gravity oil cups are applied directly to the parts needing oil and are generally used on cheaper marine and stationary engines.

Q. What is a compression or pressure feed lubricator?

A. A typical pressure feed lubricator is outlined at Fig. 116. This consists of a small tank holding one or two quarts of oil, which is attached to the motor at any convenient point and which is designed so the oil it contains may be put under pressure and forced through a pipe to a sight feed manifold fitting from which the individual oil leads go to the points needing oil. The pressure is usually obtained from the exhaust or by a pipe leading to the crank case interior. A small check valve fitting is carried at the end of the pressure pipe on the oil container in such a way that the air or gas under pressure will raise the check valve from its seat and flow

into the oil container. As the check valve seats when the pressure of gas in the tank is sufficiently high the confined gases cannot escape and must force the oil out of the tank. The oil flows to the top of the sight feed arrangement where the amount dropping can be regulated at will and as the manifold is always carried higher than the bearing point the oil flows principally by gravity assisted to some extent by a slight pressure escaping from the oil container. As a lubricator of this nature will supply lubricant as long as there is pressure in the tank and as no oil is needed after the engine

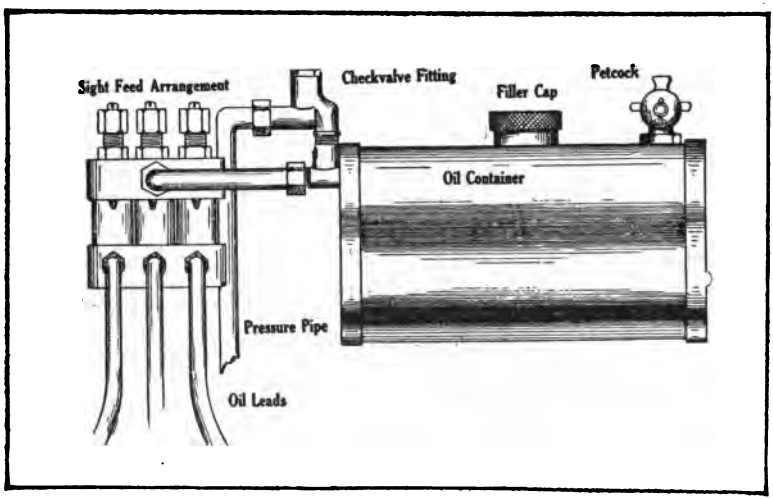


Fig. 116.—Simple Compression Feed Oiler in Which Oil is Supplied From Container by Crank Case or Exhaust Pressure.

stops it is desirable to fit the container with a small petcock or relief valve which can be opened when the engine is stopped to relieve the pressure on top of the oil and thus interrupt the supply to the bearings.

Q. Name principal methods of mechanical oiling and state their advantages.

A. There are two main methods of oiling a power plant by mechanical means, the most common one involving a single pump which keeps the oil in circulation from the oil sump or container integral

with the crank case to the crank compartments, where it is picked up by the connecting rods and splashed around. The other is by individual lead sight feed oiler in which each separate bearing is supplied by its own pump plunger through an oil tube. A defect of the sight feed gravity oiling method is that the flow of oil might be stopped by any small particle of foreign matter in the oil tube or even by thickening of the oil due to lowering temperature so the bearing points would be deprived of lubricant.

Much trouble resulted from this source and positive systems by which oil must be delivered to the bearing points as long as the power plant is kept in operation were evolved. With a powerful pump

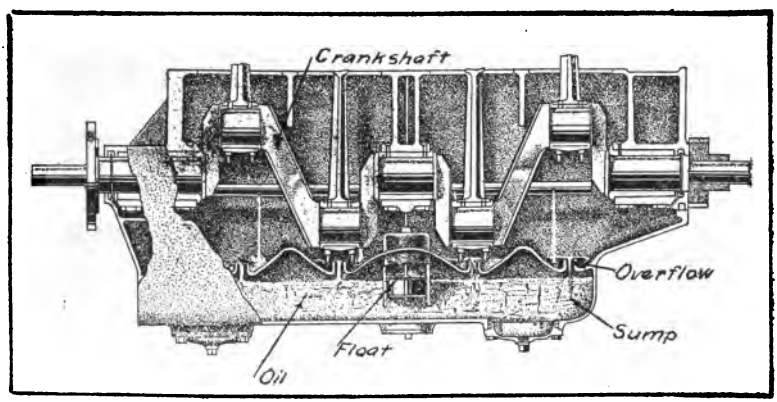


Fig. 117.—Outlining Action of Constant Level Splash System of Haynes Car.

forcing the lubricant through the oil supply tubes it is difficult for any accumulation of lint or small piece of wax carried by the oil itself to constrict the bore of the tube and retard the flow of lubricant. The pumps have sufficient pressure so the oil, which is an incompressible liquid, will be forced to the bearing points and clear the tube or passage of obstructions tending to impede its flow. The individual lead form of oiler or mechanical oiler having a large number of individual pumps is seldom used at the present time as practically all automobile engineers favor the simpler and more positive self-contained systems.

Q. Describe action of constant level splash system.

A. The arrangement of the crankcase interior, when used in connection with a constant level splash system, is clearly outlined at Fig. 117. As will be evident the crankcase is divided into two parts, the lower portion or sump being separated from the upper part in which the crankshaft revolves by a cast partition wall of corrugated form which practically divides the interior into four compartments, one for each connecting rod. A small standpipe extends from each compartment to a sufficient height so any accumulations of oil that would tend to raise the level of lubricant above the predetermined point will overflow and pass back from the crank

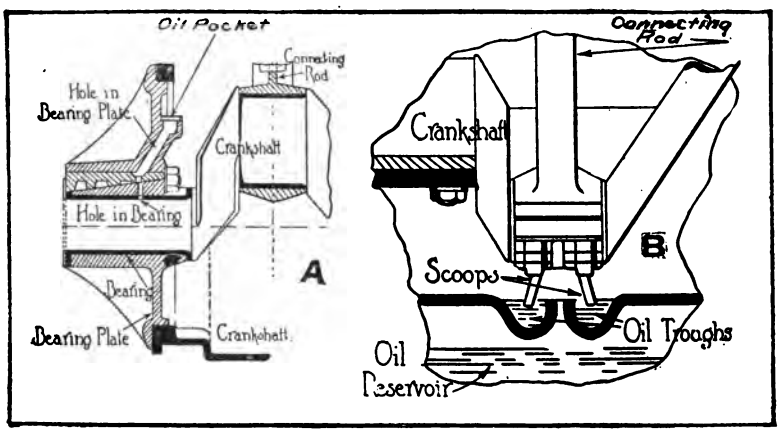


Fig. 118.——Methods of Supplying Oil to Bearings. A—Oil Pocket Above Main Bearings Which Collects Lubricant. B—Showing Scoops at Bottom of Connecting Rod to Pick Up Lubricant From Troughs in Crankcase.

compartments to the sump beneath them. The main bearings are oiled as shown at Fig. 118-A. The oil accumulates in the oil troughs shown at Fig. 118-B and is picked up by scoops attached to the lower connecting rod bearing cap and splashed around the interior of the crankcase. The spray or oil mist collects on all working parts and a portion of the oil will be caught by oil pockets such as shown at *A* and diverted to the bearing, while some of the lubricant will be splashed on the cylinder walls where it will be spread out and

picked up by the rapidly reciprocating piston and reduce friction between the piston and piston rings and cylinder wall.

The diagram at Fig. 119 outlines clearly all parts of a simple constant level splash system having a sight feed on the dash. The direction of oil flow can be easily determined by the arrows. The lubricant is drawn from the sump or container at the bottom of the crank case through a screen attached to the intake pipe of a gear driven oil pump. The pump discharge goes to the sight feed

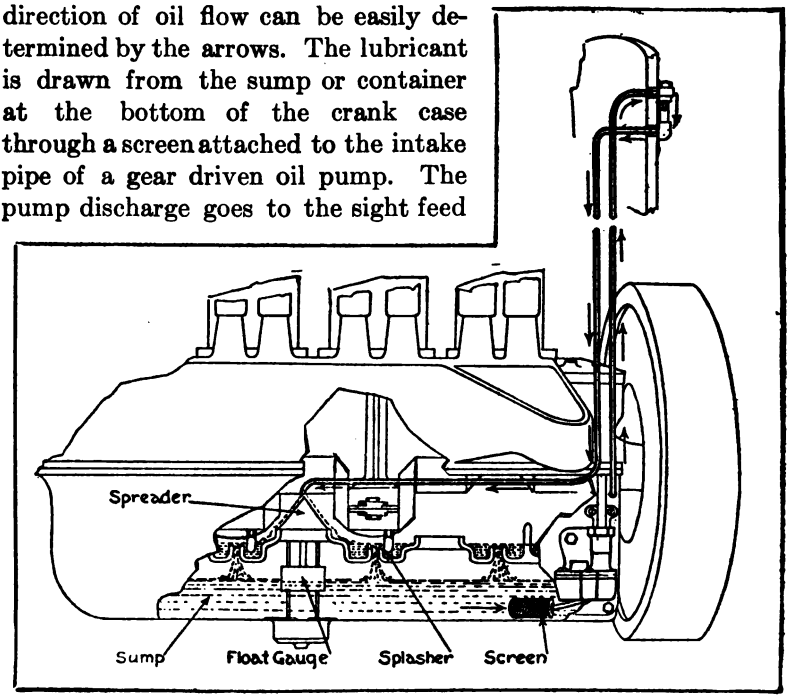


Fig. 119.—Overland Constant Level Splash Lubrication System.

on the dash and a pipe from the lower portion of this indicator returns the lubricant to spreader members which divert the liquid into the oil troughs under the connecting rods. With this method of lubrication the oil is kept in constant circulation and as the level is always maintained at the proper height in the oil troughs, there is no possibility of the engine becoming under or over lubricated and a constant supply of oil is insured under all operating conditions.

Q. Can oil be circulated without pumps?

A. It is not always necessary to supply a gear driven pump to

circulate the oil around a power plant interior, as in some the design is such that the flywheel itself serves as an oil distributing member. A typical system of this nature is shown at Fig. 120. The power plant crankcase is inclined toward the rear end so that a pocket is formed in which the oil can collect to a certain height that will insure its being picked up by the periphery of the rapidly moving flywheel rim. The oil thrown from the flywheel is collected by a main oil pipe to an oil feed regulator controlled by the accelerator or throttle lever. From this point a portion of the oil is diverted to an oil duct which joins the four cylinders, while the

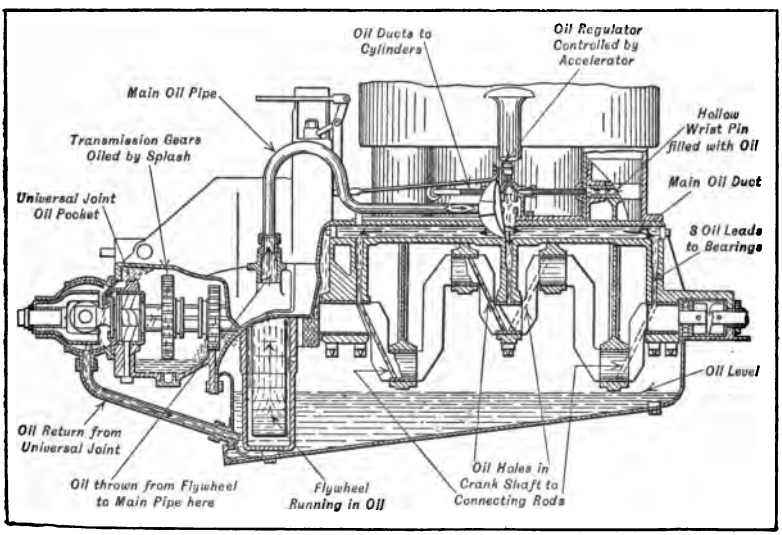

Oil Ducts to Cylinders
Oil Regulator Controlled by Accelerator
Main Oil Pipe
Transmission Gears Oiled by Splash
Hollow Wrist Pin filled with Oil
Main Oil Duct
Universal Joint Oil Pocket
3 Oil Leads to Bearings
Oil Level
Oil Return from Universal Joint
Oil thrown from Flywheel to Main Pipe here
Flywheel Running in Oil
Oil Holes in Crank Shaft to Connecting Rods

Fig. 120.—Oil Supply System of Hupmobile Motor Depends on Flywheel to Circulate Lubricant.

remainder flows into the main oil duct cored out in the crankcase to the three main bearings. Oil passages are drilled from the main bearings to the crank throws and these are thoroughly filled with oil which after lubricating the connecting rod caps is thrown about the interior of the engine by centrifugal force and insures that all interior parts not supplied directly by the oil ducts will receive lubricant. Oil thrown by the flywheel is also diverted to the trans-

mission gears and universal joint, from which it is returned by a pipe joining the universal joint casing with the flywheel pocket at the rear of the crankcase.

Q. What types of pumps are used to circulate oil?

A. Two forms of pumps are used to circulate oil, the gear form which is shown at Figs. 119 and 121 and the plunger pump clearly outlined at Fig. 122. The gear pump consists of a pair of spur gears, having large teeth, meshing together in a closely fitted metal

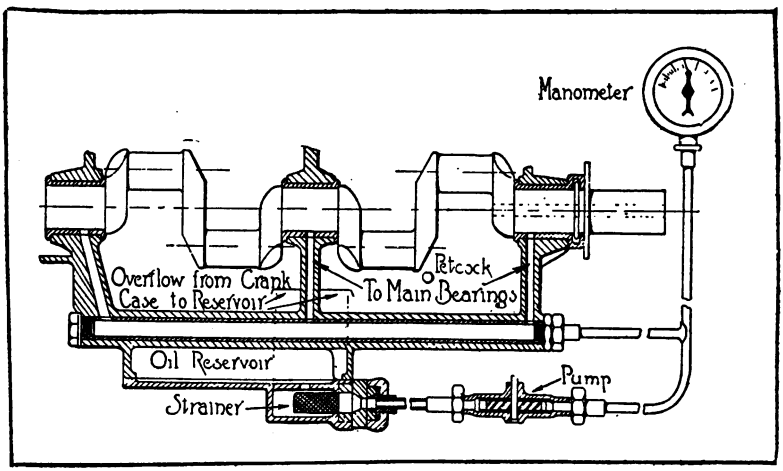


Fig. 121.—Method of Lubrication by Supplying Oil to Main Bearings by Pressure Supplied by Gear Pump.

case. One of the gears serves as the driving member and is turned by any suitable mechanical connection with the engine crankshaft or camshaft. The plunger pump is usually cam operated, as indicated at Fig. 122, because it works with a reciprocating motion instead of a rotary movement. Both forms outlined are positive though the plunger form is capable of exerting more pressure on the oil than either the spur gear or eccentric forms also widely used.

Q. Why should oil supplied to engines be carefully regulated?

A. It is imperative to insure efficient engine action that the oil supplied in measured quantities that will be just right for the

conditions under which the power plant is operated. If the lubricating oil is introduced in excessive quantities a considerable portion will be forced into the combustion chamber, where it will be burned by the excessive heat present at that point and produce carbon deposit in the interior of the cylinder head. When an engine is supplied with too much oil the surplus will escape at all pos-

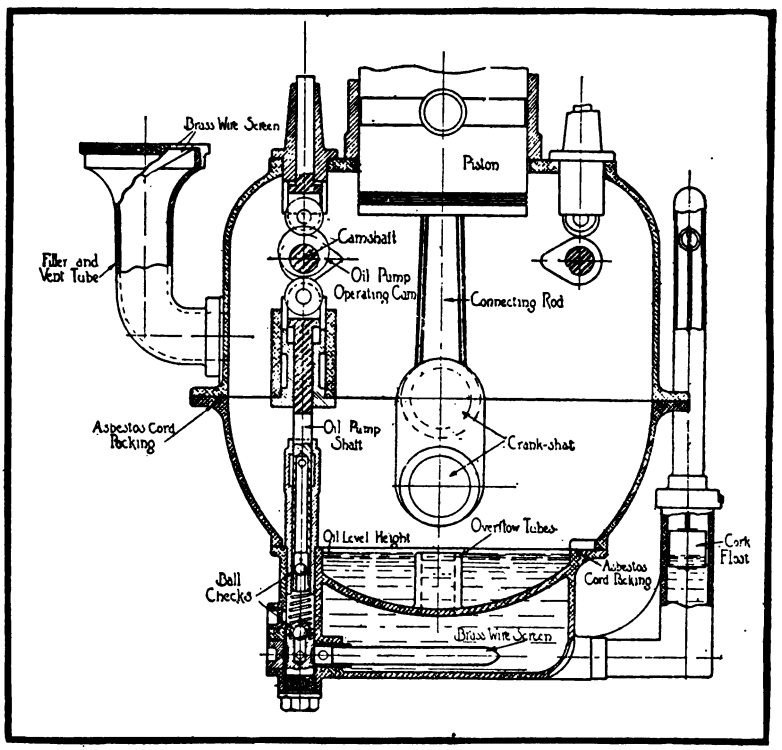


Fig. 122.—Sectional View of Commercial Car Crank Case Showing Oil Supply by Plunger Pump.

sible bearing points and the wasted lubricant performs no useful service. If the oil is not supplied in sufficiently large quantities the bearings will heat because of the friction between their parts and some of the engine power will be lost. If the oil supply is interrupted through accidents, the part may heat up sufficiently so

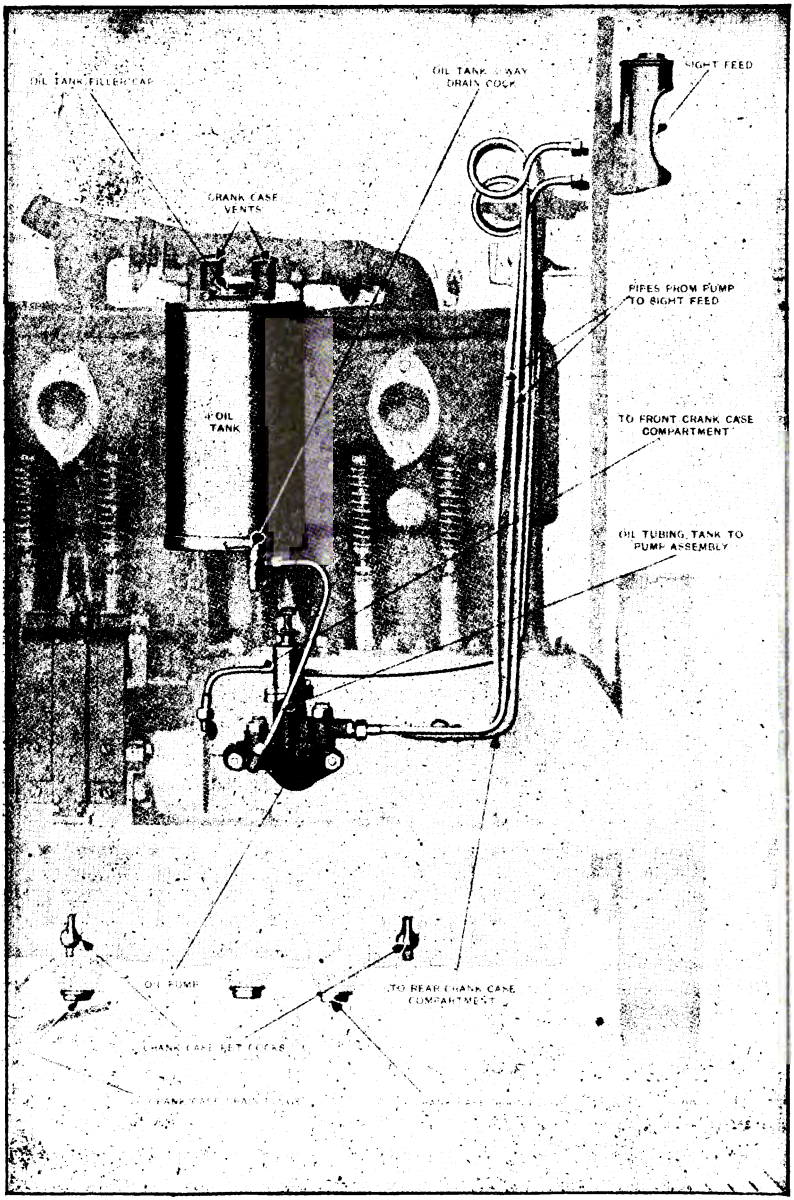


Fig. 123.—Showing Oiling System for Engine Lubrication Employed on Packard Motor Truck.

that the bearings will be burnt, cylinder and piston walls scored and other damage done.

Q. How can oil supply be regulated?

A. One of the advantages of the constant level splash system of lubrication is that the amount of oil required is determined by experiment at the factory and the motorist does not have to regulate the oil feed to any extent. The operator's responsibility ceases when the oil container has been filled with a sufficient quantity of good engine oil. On some of the individual pump mechanical oilers the stroke of the pumps may be varied to alter the oil feed. Sight feed lubricators are often provided with needle valves to regulate the amount of oil passing through the orifice they control in a given unit of time.

Q. Describe some typical lubrication systems used on high grade cars.

A. The oiling system of the Packard six cylinder motor is clearly outlined at Fig. 124. In this the oil is carried in a sump formed integral with the crankcase and is taken from that point by a pump and delivered to a manifold pipe extending along the side of the motor crankcase. This manifold communicates with the main bearings, as well as to the timing gear assembly at the front end of the motor. The crankshaft is provided with drilled passages so the oil supplied by the oil manifold lubricates the connecting rod big ends after it passes from the main bearings. The cylinder interiors, pistons, valve plunger guides, and other parts are thoroughly oiled by the oil spray always present in the crank case. A manometer or pressure gauge is carried on the dash board and is attached to the end of the motor oil manifold. This indicates at all times if oil is being delivered to the bearing points. If the pressure of oil becomes too great in the manifold as sometimes occurs at high engine speeds, a relief valve is provided which permits the excess lubricant supplied by the pump to bypass back into the crankcase interior.

The system of lubrication employed on Packard trucks is shown at Fig. 123. In this the oil is drawn from a tank by an oil pump and forced through the sight feed on the dash, back to the crank-

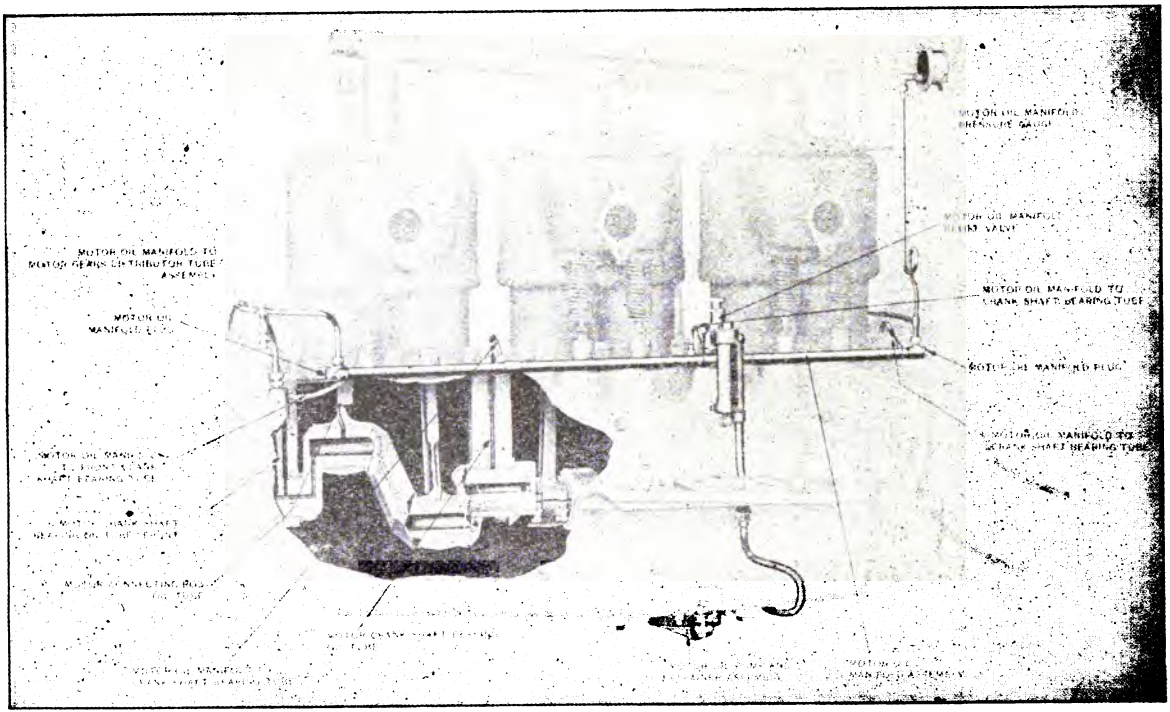


Fig. 124.—Lubrication System of Packard Six-Cylinder Engine.

case interior, where it collects in the front and rear crankcase compartments to a level indicated by the petcock screwed into the sides of the crankcase. The interior of the engine is thoroughly lubricated by the splash system.

In the Pierce Arrow cars practically the same arrangement as used in the Packard six cylinder and several other leading cars is used. This system is depicted at Fig. 125 and involves the use of a gear driven oil circulating pump having its suction side connected to the sump at the bottom of the crankcase and its delivery pipe to a manifold which goes to the main bearings of the drilled out

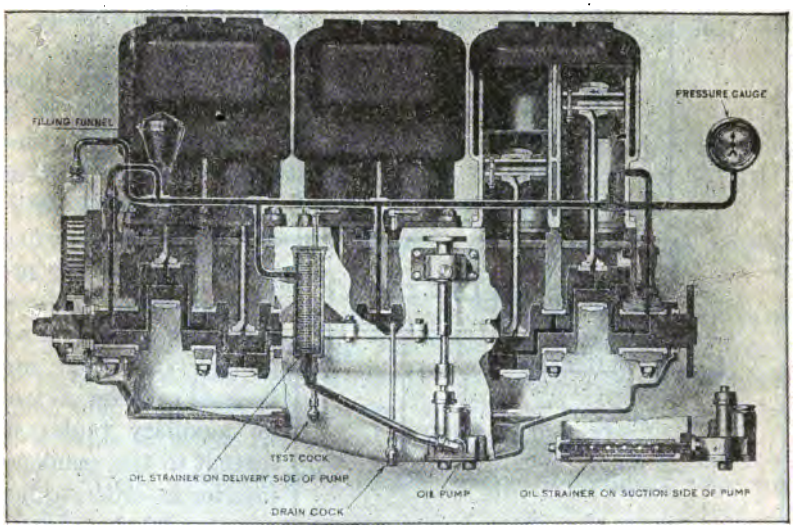


Fig. 125.—Oiling Method Used in Lubricating Pierce Arrow Six-Cylinder Power Plant.

crankshaft. A feature of this system is the use of an oil strainer or filter screen on both suction and delivery sides of the pump. Both of these screens may be readily removed for cleaning purposes and insure the delivery of only perfectly clean oil to the bearing points. Two petcocks are provided on the side of the crankcase. The one at the bottom is a drain cock through which the sump may be emptied at any time while the testcock indicates if the oil level in the sump is sufficiently high.

Q. How can oil be introduced to the crankcase interior in emergencies?

A. Practically all power plants utilizing the constant level splash or manifold supply systems in which the oil is carried in a container integral with the crankcase have a filler tube or funnel that communicates directly with the crankcase interior, through which the lubricating oil is poured. In some forms of power plant where the feed is by individual pump mechanical oilers that are set for normal operating conditions it is sometimes desirable to provide a hand operated pump of the simple plunger type that may be used to draw oil from an auxiliary tank and force it to the crankcase interior in order to help out the lubricating system under abnormal operating conditions such as speeding and long stretches of low speed gear work where the engine must run fast and pull hard. A simple form of oil pump adapted for this purpose is clearly outlined at Fig. 126.

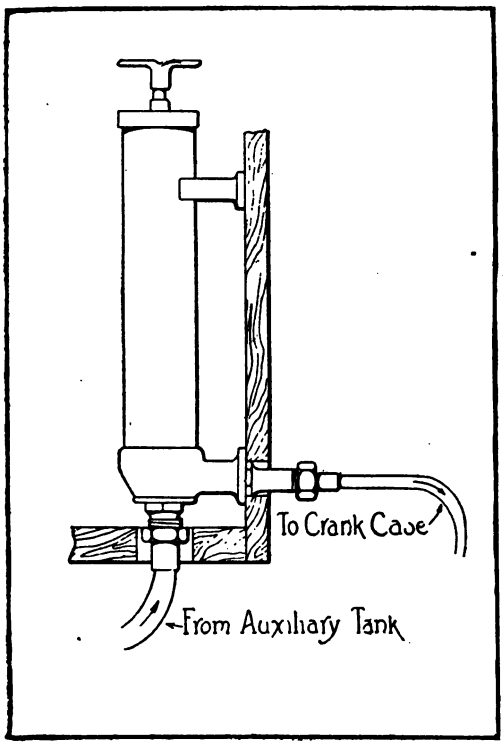


Fig. 126.—Hand Pump Sometimes Used to Inject Oil to Engine Base as an Auxiliary to the Regular Lubrication System.

LESSON THIRTEEN

COOLING THE GASOLINE ENGINE BY AIR

Q. Why is it necessary to cool the cylinder of a gas engine?

A. The rapid succession of explosions taking place in the combustion chamber, which means that temperatures higher than 2000 degrees F. exist at that point, temporarily causes the cylinder to become heated, and some method of absorbing the surplus heat must be provided.

Q. What part of the cylinder is hottest?

A. The combustion chamber or cylinder head is hotter than the rest of the cylinder because it is exposed directly to the hot gases at all times and is subject to the maximum temperature.

Q. What would be the effect on the valves, if the engine was not cooled?

A. If no provision was made for absorbing the excess heat present in the combustion chamber the inlet and exhaust valves would warp, the valve head seats would become burnt so these members could not hold compression and the stems would be liable to stick while in action.

Q. What would happen to the piston if cylinder was not cooled?

A. The piston would expand to such a point that it would have much friction in the cylinder and on account of the high temperature, which would burn away the lubricating oil, it would not be long before the piston would seize in the cylinder and perhaps become expanded by the heat to such a point that it could not move.

Q. Describe the possible methods of cooling.

A. Gas engine cylinders may be cooled by direct application of currents of air or by circulating water through a suitable jacket around the hot portions.

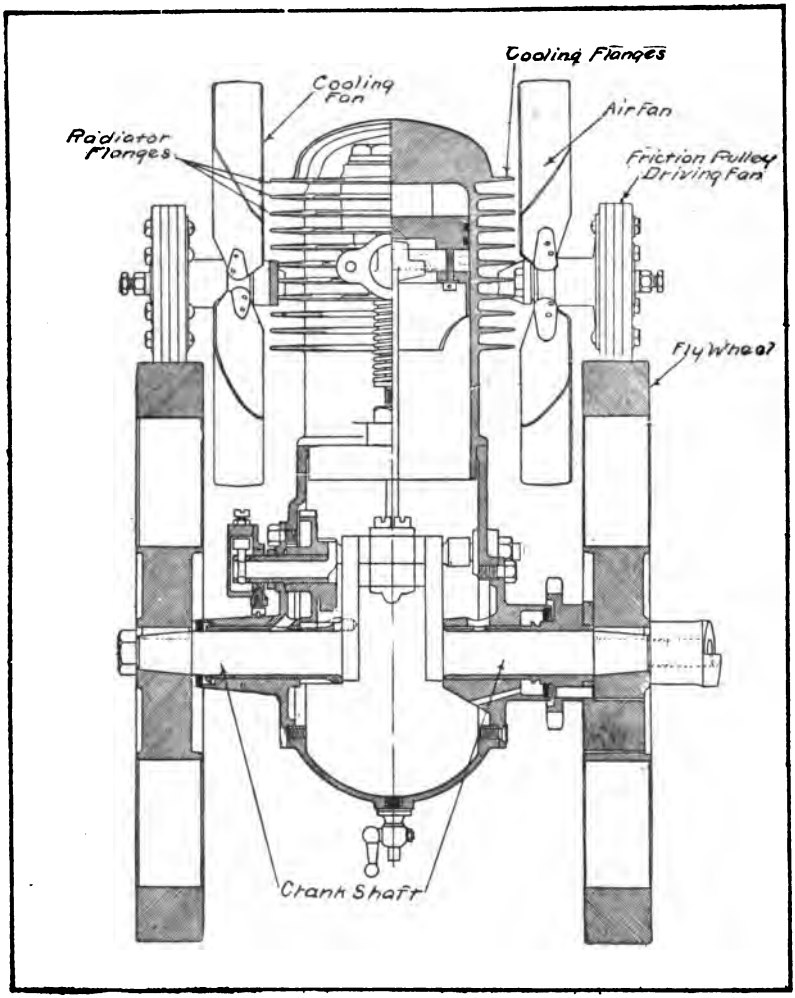


Fig. 127.—Simple Air-Cooled Engine With Radiating Flanges Cast Integral With Cylinders and Air Blast for Cooling From Friction Driven Fans.

Q. What is the simplest method?

A. The system of direct cooling by air is simpler than the indirect systems of cooling by water.

Q. Will air absorb heat as readily as water?

A. The heat absorbing power of air is very much less than that of a similar volume of liquid such as water or oil.

Q. What is necessary in order to cool successfully by air?

A In order to compensate for the lessened power of heat absorption possessed by air it is necessary to provide more radiating surface from which the heat can be taken and also to use rapidly moving currents of air passing over the augmented surface.

Q. Can an engine cylinder be cooled too much?

A. It is possible to cool a gas engine cylinder to such a point that the efficiency of the motor will be greatly reduced and cause it to lose power.

Q. What is the permissible temperature of an air-cooled cylinder?

A. Theoretically a cylinder may become heated to the point where the cylinder oil is not affected unduly by the heat, but in actual practice owing to the facility w th which metals may become distorted by expansion due to heat it is not recommended that temperatures exceeding 325 to 350 degrees F. be exceeded.

Q. What is the temperature of a water cooled cylinder?

A. The temperature of a water cooled cylinder must a ways remain below 212 degrees F. or the boiling point of water because if the cylinder is allowed to become hotter than this it will produce boiling and rapid evaporation of the cooling liquid.

Q. What percentage of heat is lost through the cooling system?

A. The amount of heat lost through the jacket water of the average internal combustion cylinder is given a different value by various authorities, this ranging from 40 to 55% of the total heat generated by the combustion of the gas in the cylinders.

Q. Is it desirable to reduce this heat loss?

A. If it is possible to reduce the loss of heat units one will obtain greater efficiency from a given amount of fuel because more heat is turned into power. As a rule the loss with an air cooling system is considerably less, and air-cooled engines are more efficient than the water-cooled forms.

Q. How many methods of air cooling are used?

A. There are two methods of air cooling, one depending on the radiation of heat from a largely increased surface alone, the other by convection and radiation, this involving passing a current of air at high velocity over the radiating surfaces.

Q. Describe simple radiating systems.

A. A simple radiation system is used only in some forms of stationary engines of small power. To cool by radiation it is merely necessary to increase the external area of the cylinder by any suitable means. The air immediately surrounding the cylinder is heated by contact with it and as it is lighter than cool air it rises and its place is taken by cooler, heavier air which in turn becomes heated and makes way for more air at a lower temperature than that surrounding the cylinder. As should be expected cooling by this method is too sluggish for general use, so the combined radiation and convection systems are generally employed in motor vehicle service.

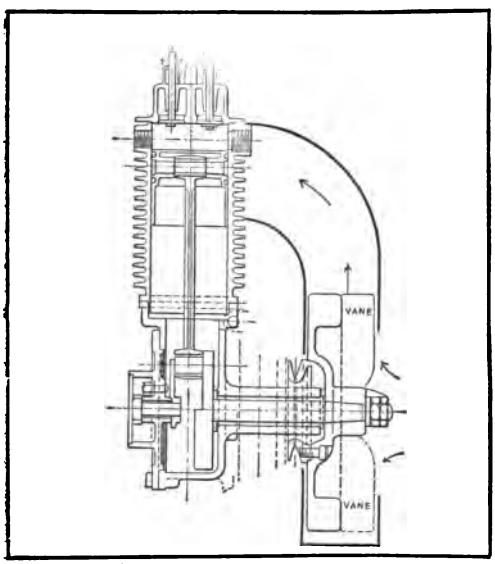


Fig. 128.—Air-Cooled Engine Utilizing Air Blast From Blower Type Fan Flywheel.

Q. Describe air cooling by radiation and convection.

A. A simple single cylinder air cooling engine in which the heat absorption is by radiation and convection is outlined at Fig. 127. In this power plant the cylinder is provided with radiating flanges, which are swept by air blasts set up by cooling fans placed at each side of the cylinder and driven by frictional contact with the

flywheel rim. The more rapid passage of the air currents produces a better cooling effect than would be obtained by the simple radiation method. On some types of fast moving vehicles where the engine is exposed, as in motorcycle practice, it is not necessary to provide a fan for producing the air blast because these are automatically produced by the rapid movement of the cylinder through the air.

Q. What are the usual methods of increasing the effective radiating surface?

A. The cylinder is generally provided with flanges which may be

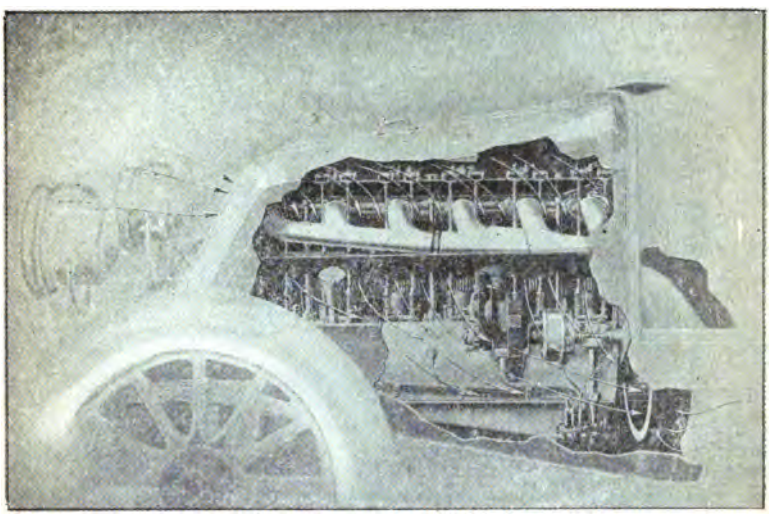


Fig. 129.—Franklin Method of Air Cooling by Air Blast Induced Past Cylinders by Blower Type Flywheel.

cast integral or which may be made of some metal that is a better conductor of heat than cast iron and forced in place around the cylinder by shrinking them against the smoothly machined exterior. Sometimes the cylinder is provided with inserted pins or with projecting spines cast integrally. Other forms have been made in which metal combs have been fitted to the cylinder either by peening these in grooves milled longitudinally on the cylinder walls or by inserting

them in the mould and pouring in the molten metal when the cylinder is cast.

Q. Which is the most efficient method of flange application?

A. Owing to the loss of heat at joints the integrally cast flange is generally preferred to applied flanges.

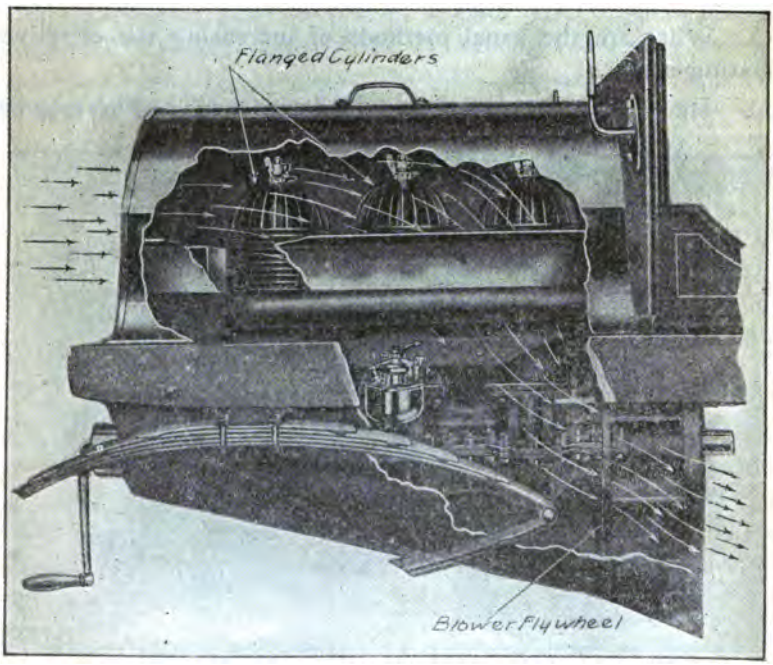


Fig. 129A.—Simple Air-Cooling System Employed On Chase Two-Cycle Motor Truck Power Plant.

Q. How are air currents produced for cooling cylinders?

A. Air currents may be directed against the cooling flanges by means of simple fans, as shown at Fig. 127, or by flywheel suction as shown at Figs. 128 and 129. In some forms of aeroplane power plants, notably the Gnome motor, which has revolving cylinders and which is illustrated at Fig. 130, the cylinders are cooled by rapid rotation through the air.

Q. Describe air cooling by flywheel suction.

A. The system of air cooling employed on Franklin motor cars is typical of the method of inducing air current by flywheel suction. This power plant is shown at Fig. 129 and the path of the air currents can be readily ascertained by following the arrows indicated. The motor is carried in a practically air tight compartment, except for an opening at the front end of the hood, and the only way air entering may escape is through the rear end of the motor compartment. The flywheel is a special form having a series of curved blades which have a suction effect as they revolve and

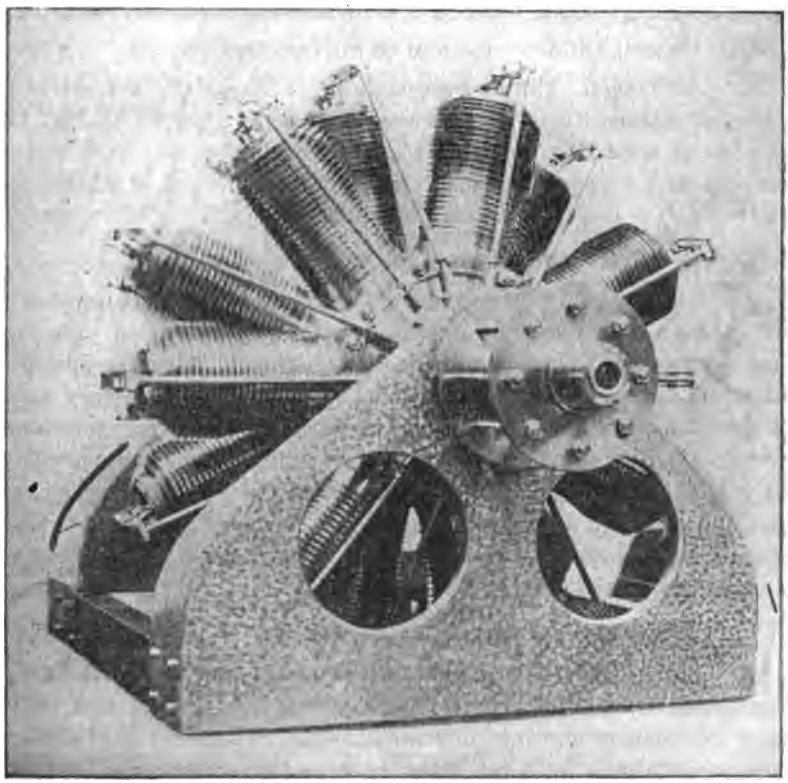


Fig. 130.—Air-Cooled Motor Having Fourteen Revolving Cylinders Used for Aeroplane Propulsion.

tend to exhau t the air from the motor compartment. During the entire period of time the engine is in operation the flywheel produces a partial vacuum in the motor compartment by its pronounced draught creating properties and cool fresh air is constantly entering through the front of the hood to replace the warm air drawn out by the blower flywheel. Before the entering air can leave the motor compartment it must pass through sheet metal jackets which surround the cylinders and as it brushes by the vertical radiating flanges it becomes heated and the surplus heat is thus taken from the cy inder. A similar system used successfully on the Chase motor truck is outlined at Fig. 129A.

Q. Describe blower system of air cooling.

A. Air cooled cylinders are sometimes cooled by a blast of air directed against them by a pressure blower, as shown at Fig. 128, instead of a suction fan. This form of blower draws in a cool air current and forces it against the cylinders through a suitable air pipe which is connected to an air jacket surrounding the cylinders.

Q. What are the advantages of air cooling?

A. Besides being more efficient as regards fuel consumption an air cooled engine may be operated under conditions of extremely low temperature that would interfere seriously with the operation of water-cooled cars. During cold weather it is necessary to fill the radiators of water-cooled cars with anti-freezing compounds which require constant attention and which in some cases are actually harmful to the various components of the cooling system. An air-cooled motor will work as well in cold weather as it will during the warmer season and there is no necessity of making any changes in the cooling systems to provide for lower temperatures.

Q. What are the defects of air cooling?

A. One of the main defects of air-cooled motors, as heretofore constructed, has been the necessity of careful driving and intelligent lubrication and mixture adjustment. The air-cooled motor is not as suitable a form for general use as the water-cooled type because it becomes overheated under certain conditions of abuse, where the overheating of a water-cooled engine under similar con-

ditions would not be so apparent on account of the greater capacity of a water-cooling system to absorb heat. When used under conditions of overload or maximum power generation for extended periods, the air-cooled engine is not as suitable as the water-cooled type.

Q. Where is air cooling particularly desirable?

A. Air-cooled engines are widely applied as power plants where maximum simplicity and lightness for a certain horse power are essential.

Q. Where are air cooled engines widely used?

A. Air-cooled engines have been almost universally applied to motorcycle propulsion, have been used extensively as light portable power plants for farm use and have also received some application in aeroplane service.

LESSON FOURTEEN

TYPICAL WATER COOLING SYSTEMS

Q. What is the common method of cooling by water?

A. In usual water cooling systems the cylinder is provided with a water jacket which is kept constantly filled with water, this passing out of the jacket when it becomes heated and returning again when it has been cooled by external means.

Q. Name the two systems of water cooling.

A. There are two common methods of cooling by water, the simplest of these being the thermo-syphon or natural system; the other is the pump circulation method.

Q. How does the thermo-syphon system operate?

A. The conventional arrangement of parts of a thermo-syphon cooling system is outlined at Fig. 131. A radiator or water container supplies water to the lower portion of the water jacket by means of a manifold pipe and after the water becomes heated it passes out of the top of the water jacket, through another manifold to the top of the radiator. The circulation is maintained by a natural law that hot water being lighter than cool water will rise and be replaced by water at lower temperature. In the system outlined the heated water from the engine passes through the radiator and is cooled and falls to the bottom of the radiator where it is again conducted to the bottom of the cylinder. Circulation is maintained automatically as long as the engine is in operation and the radiator is filled with water.

Another method of cooling by the thermo-syphon system, in which the radiator is carried at the back of the power plant instead of at the front end, is shown at Fig. 132. The principal parts consist of a radiator, which serves as a water cooler and storage tank,

a centrifugal fan member to draw air through the radiator, and suitble pipes to connect the water jacket with the upper and lower portions of the radiator respectively.

Q. What precautions are necessary to successfully use thermo-syphon cooling?

A. Where the water is circulated by natural means it is necessary to have a radiator of large capacity and also large water jackets and manifold pipes as circulation due to the heating and cooling of water is more sluggish than in systems where a pump is employed.

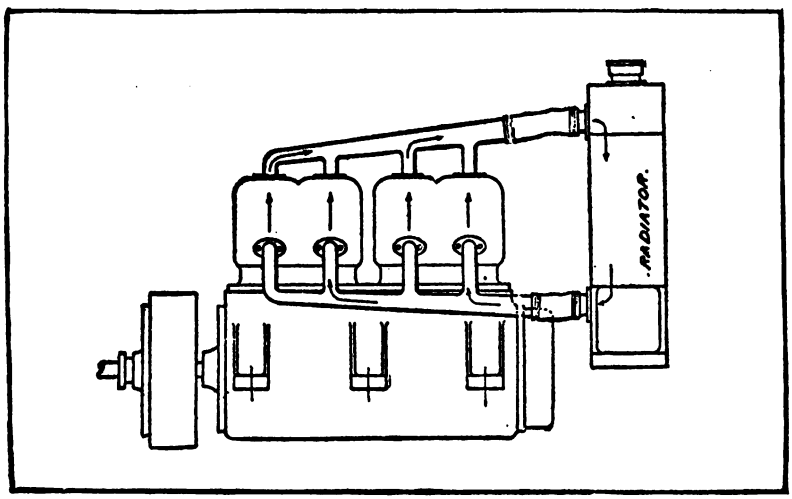


Fig. 131.—Illustrating Action of Simple Thermo-Syphon Water-Cooling System.

Thus large water passages are necessary so the flow of liquid will not be impeded by small water spaces or resistance of small bore water pipes.

Q. What are the advantages of the forced circulation method?

A. When a pump is employed to circulate liquid, as shown at Fig. 133, the cooling system may be made lighter because less water is needed in the radiator and the water pipes and water spaces around the cylinders may be made smaller. The pump is driven by mechanical connection with the engine crankshaft and as the speed

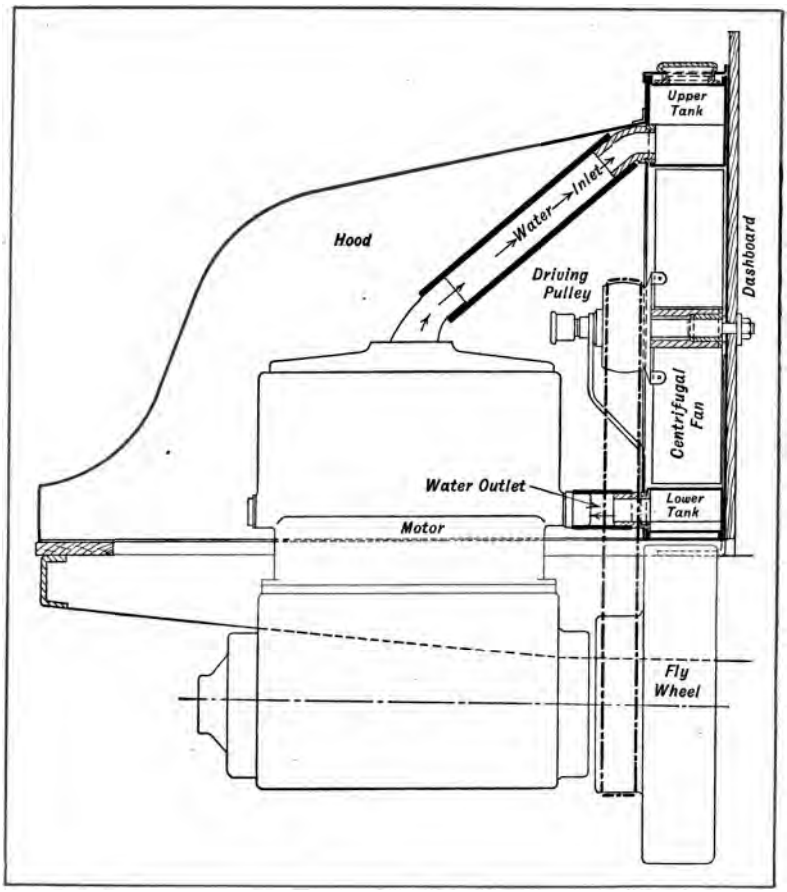


Fig. 132.—Thermo-Syphon Cooling System Employing Radiator Placed at Dash Back of Motor.

of the motor increases, the circulation of the water becomes more energetic. A more efficient form of radiator having smaller passages, which will cool the water quicker than large passages designed for free flow, may be used.

Q. Name principal parts of forced circulation system.

A. The principal parts of a forced circulation system used on Packard cars are clearly outlined at Fig. 134. The water is taken

from the lower portion of the radiator by the pump from which it is delivered to a manifold or water inlet header attached to the lower portion of the water jackets immediately under the inlet valve. The heated water is forced out of the top of the water jacket, through short cast fittings joined together by lengths of rubber hose. The water passes to the top of the radiator and as it flows through the narrow passages it becomes cooled because the tubing of which the radiator is composed is kept at a low temperature

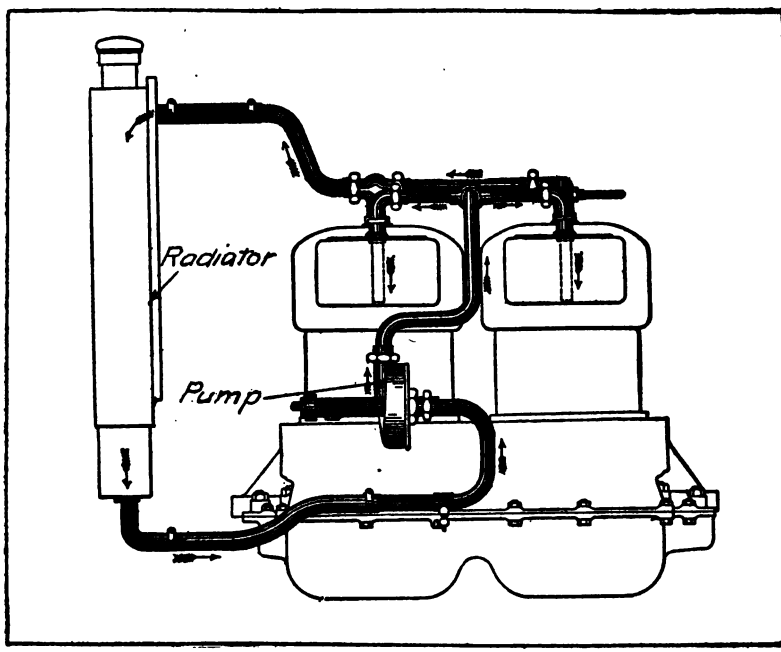


Fig. 133.—Conventional Forced Circulation System Employing Mechanically Driven Pump to Insure Movement of Water.

by a current of air drawn through the radiator by a V belt driven, cast aluminum fan.

Q. How many types of pumps are commonly used in water cooling systems?

A. The forms of pumps utilized to circulate the water through the radiator and water-jacket spaces are usually of the rotary type,

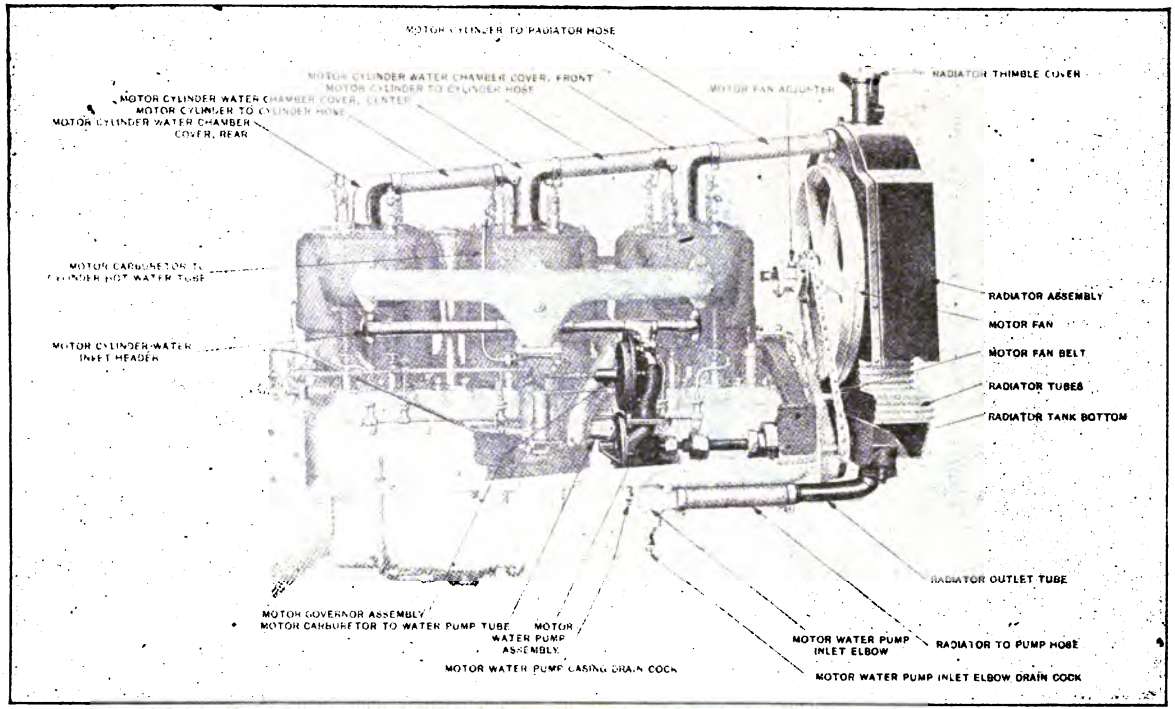

MOTOR CYLINDER TO RADIATOR HOSE
MOTOR CYLINDER WATER CHAMBER COVER, FRONT
MOTOR CYLINDER TO CYLINDER HOSE
MOTOR FAN ADJUSTER
RADIATOR THIMBLE COVER
MOTOR CYLINDER WATER CHAMBER COVER, CENTER
MOTOR CYLINDER TO CYLINDER HOSE
MOTOR CYLINDER WATER CHAMBER COVER, REAR
MOTOR CARBURETOR TO CYLINDER HOT WATER TUBE
MOTOR CYLINDER WATER INLET HEADER
RADIATOR ASSEMBLY
MOTOR FAN
MOTOR FAN BELT
RADIATOR TUBES
RADIATOR TANK BOTTOM
RADIATOR OUTLET TUBE
MOTOR GOVERNOR ASSEMBLY
MOTOR CARBURETOR TO WATER PUMP TUBE
MOTOR WATER PUMP ASSEMBLY
MOTOR WATER PUMP CASING DRAIN COCK
MOTOR WATER PUMP INLET ELBOW
RADIATOR TO PUMP HOSE
MOTOR WATER PUMP INLET ELBOW DRAIN COCK

Fig. 134.—Water Cooling System Employed on Packard Motor Cars Showing Arrangement of Components, Including Circulating Pump, Radiator and Cooling Fan.

either of the spur gear or centrifugal style. On marine motors the plunger pump is very widely used because it must lift water instead of merely circulating it from one member to another.

Q. Describe construction and action of centrifugal pump.

A. A typical centrifugal pump is shown at Fig. 135. This consists of a cast bronze casing, having a water inlet concentric with and surrounding the impeller shaft and an outlet extending from a point on its periphery; an impeller or paddle wheel carried by suitable bearings in pump case and pump cover. The impeller is revolved at fairly high speed by mechanical connection with some

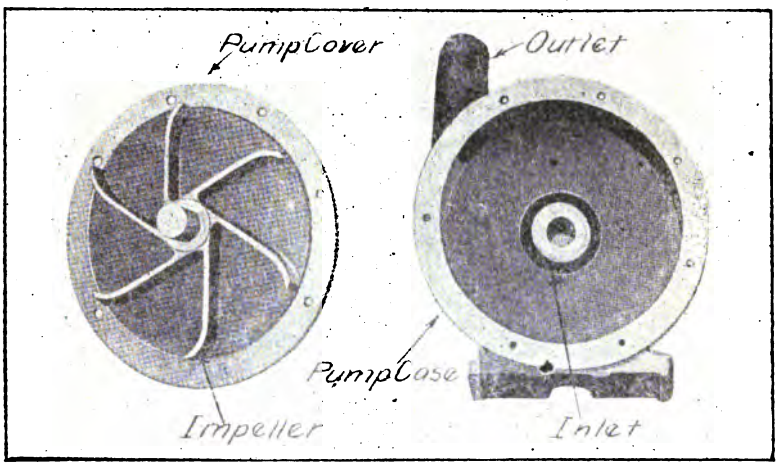


Fig. 135.—Parts of Centrifugal Water Pump.

moving part of the motor and as it revolves in the casing it forces the water entering through the inlet at the center of the impeller outwardly by centrifugal force and discharges the water from the outlet in the pump periphery. The pump intake is invariably connected to the lower portion of the radiator where the water is coolest, and the discharge or outlet is joined to the manifold connecting the lower portion of the water jackets.

Q. Outline construction and action of gear pump.

A. The gear form of circulating pump is clearly shown at Fig.

136. This consists of two spur gears that are a fairly tight fit in the pump casing, one of these being keyed to a shaft that serves as a driver while the other revolves idly on a stud fastened to the pump case. As the gears are in mesh no water can pass between them and as they rotate small volumes of water are imprisoned in the spaces between the teeth and are forced from the inlet opening around the side of the casing and are discharged through the outlet pipe.

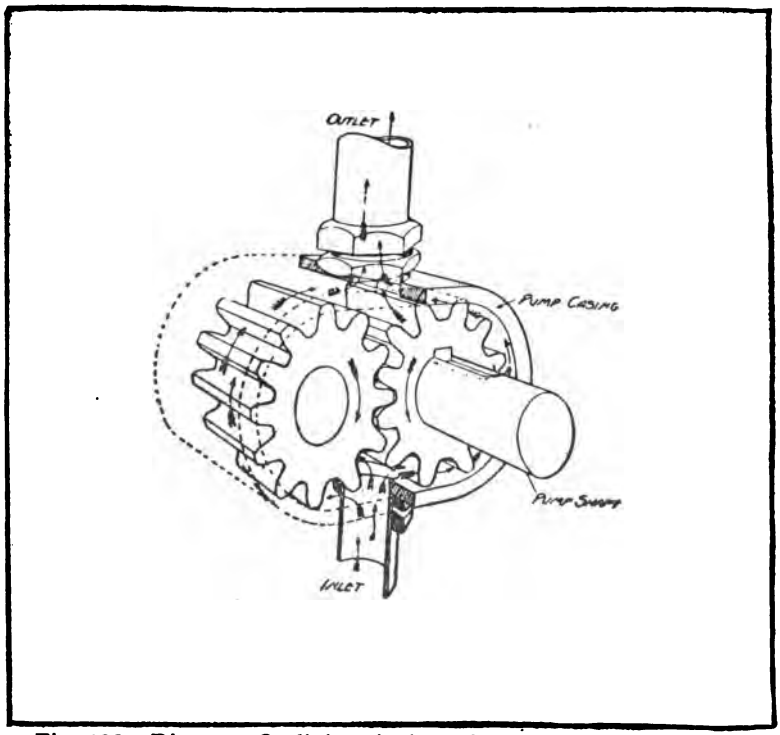


Fig. 136.—Diagram Outlining Action of Typical Gear Pump.

All parts of water circulating pumps are preferably made of bronze because this metal is not as much affected by water and does not corrode or otherwise deteriorate as rapidly as the ferrous materials steel and iron. The gear form of pump is driven by positive mechanical connection in just the same way as the centrifugal type and is utilized in the same manner.

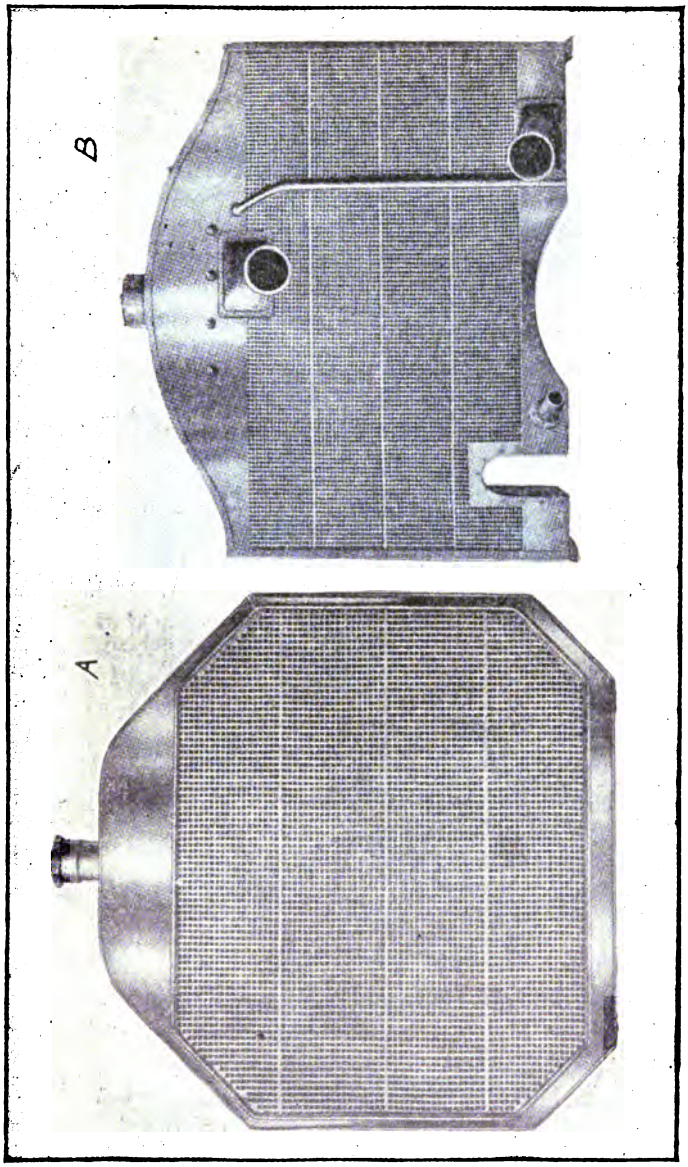


Fig. 137.—Typical Radiator Forms. A—Type Used at Front of Car. B—Cooler Construction When Placed in Back of Engine.

Q. How is the heated water from the engine cooled?

A. After the water has become heated by contact with the hot cylinder and combustion chamber walls it is discharged to the top of a cooling device termed a "radiator" by which it is exposed to a large metal surface which absorbs the surplus heat and which, in turn, is kept cool by currents of air passing through the spaces between the water tubes. Two typical radiators are outlined at Fig. 137, that at *A* being a form intended for application at the front end of the chassis, while the form at *B* is fitted at the rear of the motor and immediately in front of the dash separating the engine compartment from the body portion.

Q. How do radiators differ in form?

A. The main difference in radiators is in the formation of the water passages. In some types the water is made to flow through tubes of small diameter which spread it out in thin sheets, whereas in others tubes of greater volume are employed and the water is allowed to flow through in larger quantities. The form which divides the water into numerous small streams must be used in connection with a circulating pump of some type while that offering larger water passages can be utilized in connection with engines cooled by the thermo-syphon system.

Q. What type is the more efficient?

A. The type in which the water is divided into many small streams is the most generally used on account of its greater efficiency. Because of the narrow water passages the tubing may have a large area exposed to the influence of the cooling currents of air, and the heat is more easily extracted from a small body of water than from a larger amount.

Q. What are the disadvantages of narrow water passages?

A. It is more difficult for the water to flow through narrow passages as shown at Fig. 139, because of the resistance offered by the walls of the cooling tubes. Then again, it is easier for the small passages to become constricted with scale or impurities in the water and circulation is thus impeded. The forms of cooling tubes shown at Fig. 140 *A* and *B* when assembled together form what is known as a honeycomb cooler on account of its appearance. As will be

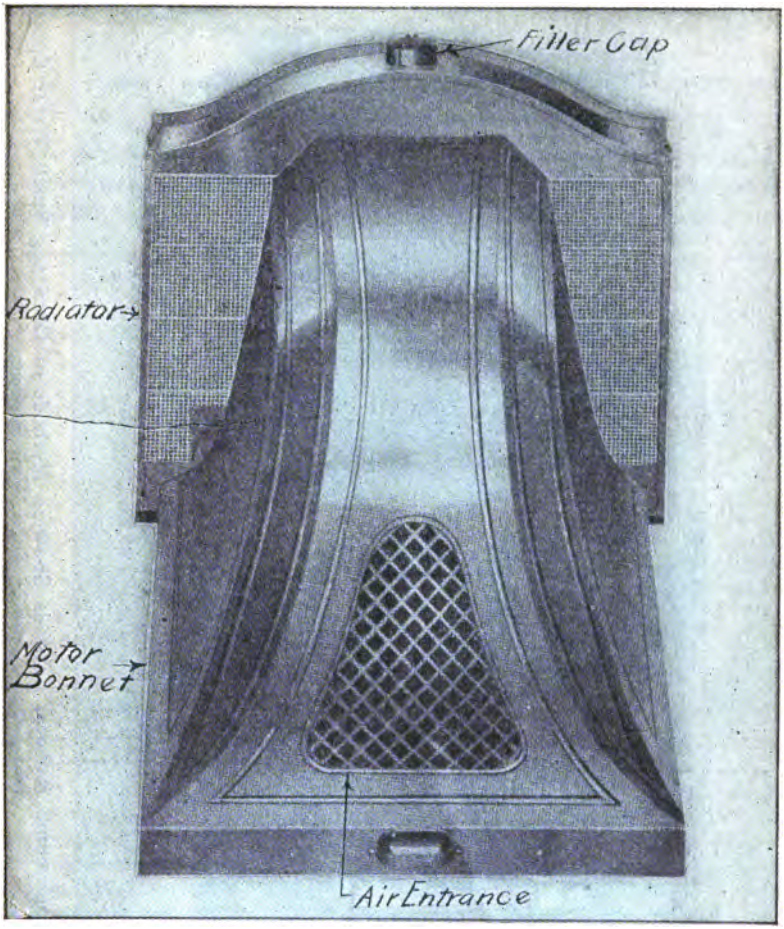


Fig. 138.—Outlining Method of Placing Dash Type Cooler Relative to Hood Enclosing Power Plant.

evident with either the square tubes shown at *A* or the zigzag passages outlined at *B* a large amount of metal surface compared to volume of water is exposed to the action of the air currents and the heat is readily extracted from the liquid. The end view of a typical honeycomb section made up of tubes as shown at *B* is outlined and

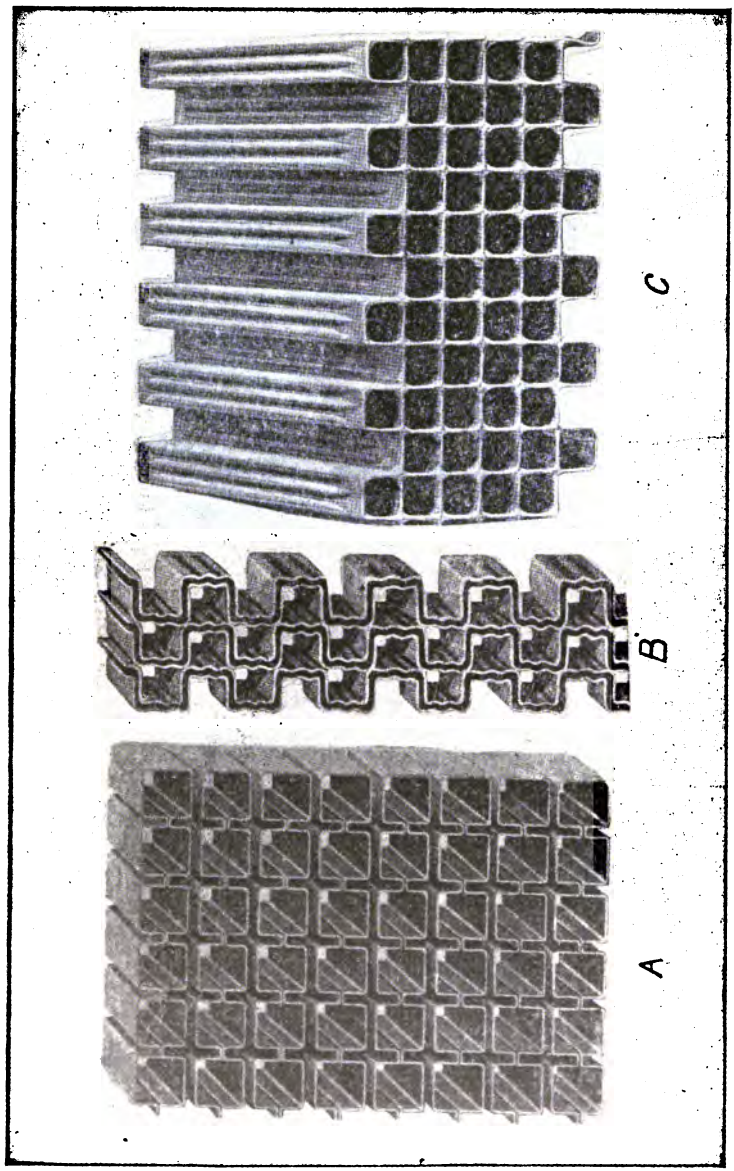


Fig. 139.—Typical Honeycomb Radiator Sections Showing Methods of Obtaining Small Water Spaces and Large Areas of Tube Wall Surface.

it will be noticed that the ends of the tubes are swaged together and firmly soldered in order to make water-tight joints.

Q. Name advantages and defects of large water passages in radiator.

A. Methods of radiator construction, which provide larger passages for the water than those previously discussed, are shown at Figs. 140 and 141. The general construction of the section outlined

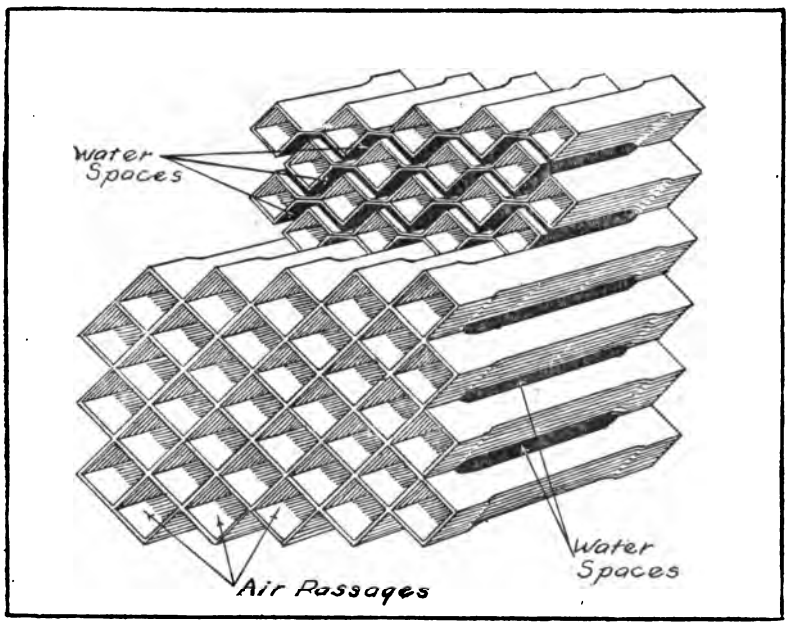


Fig. 140.—Part Sectional View of Honey-Comb Radiator Section Showing Small Water Spaces and Large Air Spaces.

at Fig. 140 is very similar to that of a honey-comb radiator but the tubes are so assembled that larger water spaces are provided between them for the water to pass through. At Fig. 141 the tubes are flattened and the effective radiating surface is augmented by means of flat cooling flanges through which the tubes are passed and to which they are firmly secured by solder when building up the radiator. The front of the section shown at Fig. 141 is provided

with a series of vertical strips which give the effect of the conventional honey-comb cooler. When water is circulated in large passages there is no retarding effect offered by the friction of the tubing walls and as the passages are direct they are not liable to become clogged with rust or other foreign matter in the water. The disadvantages of the large water passages are that a greater volume of water is needed on account of the reduced cooling effect. When water is spread out in thin sheets it is easy to cool the entire mass but when

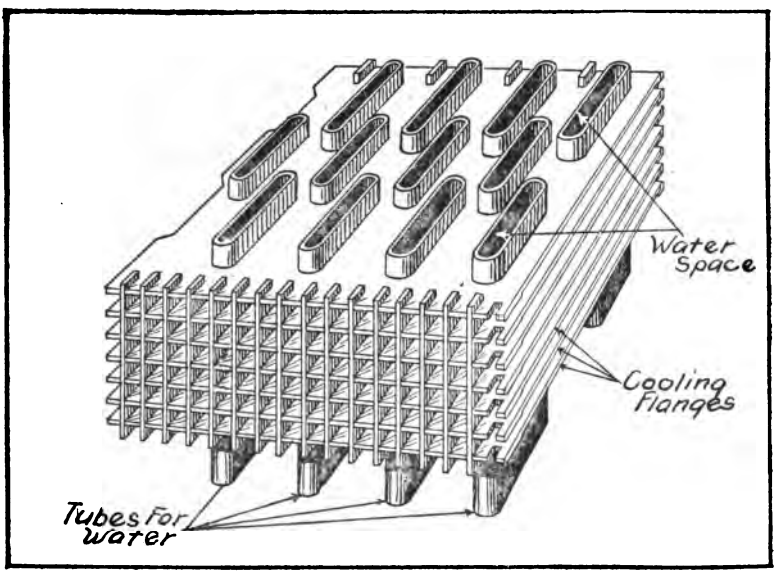


Fig. 141.—Sectional View of Flat Tube Radiator Showing Large Water Spaces Provided by this Construction.

it passes through tubes of large bore only the outside of the column of water is exposed to the cool walls of the metal tube and the inner core remains warm. Water coolers having large tubes are better adapted for the natural or thermo-syphon cooling systems.

Q. How is air circulated through radiators?

A. The usual method of supplying a stream of air is to use some form of simple fan placed immediately back of the radiator to draw the air through the spaces between the tubes while in those forms

where the radiator is carried at the rear of the hood, as shown at Fig. 138, a fan blade flywheel is often employed to produce the air draft.

Q. How are various members of the cooling system coupled together?

A. As is clearly outlined at Fig. 134 the various members of a cooling system are joined together by means of rubber and metal piping. Metal pipe is used at all points where the members are held rigid and are not liable to vibrate, while rubber hose joins two members which are liable to have motion relative to each other. For instance, in practically all cars the radiator is joined to the water jackets at the motor top and to the circulating pump by means of flexible non-metallic conductors. If metal pipe is used, the vibration is apt to crystallize it or open the joints.

Q. How are tight joints insured with the various forms of pipe?

A. Water conductors of metal are usually provided with flanged fittings which join them to the water jackets and other parts, and a tight joint is insured by interposing a gasket or packing member which is tightly squeezed between the pipe flange and the member to which it is connected and thus forms an effective seal to prevent leakage of water. In some constructions the ends of the metal pipe are pushed into a suitable opening made to receive them and a tight joint is insured by a packing gland and hemp wicking. Tight joints may be made with rubber hose by using the regular form of hose clamps which constrict around the hose and bring it in firm contact with the pipe over which it is slipped.

Q. Name two methods of constructing water manifolds.

A. Water manifolds may be cast in one piece or may be built up of various cast fittings and lengths of tubing joined together by a brazing or soldering process.

Q. Why are built-up metal manifolds preferable to cast manifolds?

A. The usual form of cast manifold unless of very large volume has rough interior walls that are apt to impede the flow of water

and that also encourage the accumulation of foreign matter because projecting particles of metal serve as anchorage points. In a built-up manifold the castings are usually so small that one has no difficulty in cleaning them out thoroughly and all roughness of interior walls may be removed. The tubing has smooth walls and with a properly built-up manifold one provides a conductor for the cooling liquid having minimum internal resistance.

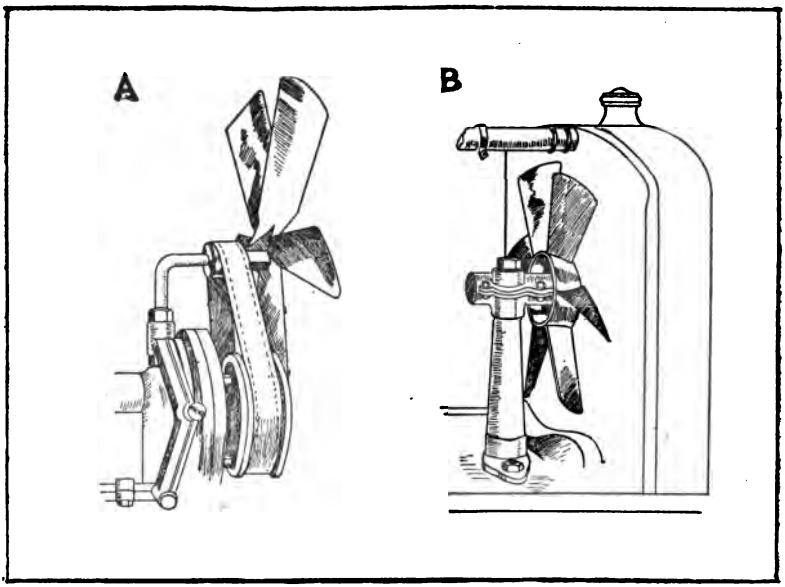


Fig. 142.—Outlining Method of Driving Radiator Cooling Fan. A—By Flat Belt. B—By Enclosed Shaft and Gearing.

Q. Name the various forms of air circulating fans.

A. Air fans may be of three main types. The most common form is a six blade fan having the blades inclined to such an angle that they draw in an air current through the radiator. Another type made in two or three blades is based more on the lines of the propellers used in marine and aeroplane service. The third type is formed integral with the flywheel and may consist of spokes having fan blade curvature and angular disposition or may be a series of blades fastened to the flywheel periphery.

Q. How are circulating fans driven?

A. Air circulating fans may be driven by positive or flexible means depending upon the preferences of the designer. Fans have been operated by positive gearing, such as bevel, spur and spiral gears, or silent chains and by flexible gearing, such as round steel wire or leather belts and flat and V leather belt. When positive gearing is employed in connection with the usual form of built-up fan it is customary to interpose some form of slipping drive between the fan hub and the gearing in order to relieve the fan of any sudden jerks which might result in throwing off a fan blade when the motor is started or stopped suddenly or when accelerated too quickly. When flexible driving means such as belts are used some form of automatic belt tension regulator is included in the design in order to keep the belt tight and insure positive drive. The flat belt is widely used on account of its simplicity and cheapness, while a V belt is utilized by some designers because it will furnish more positive drive than the flat belt and its tension does not have to be so carefully regulated. A V belt will drive when loose, whereas the flat belt is apt to slip under the same conditions.

LESSON FIFTEEN

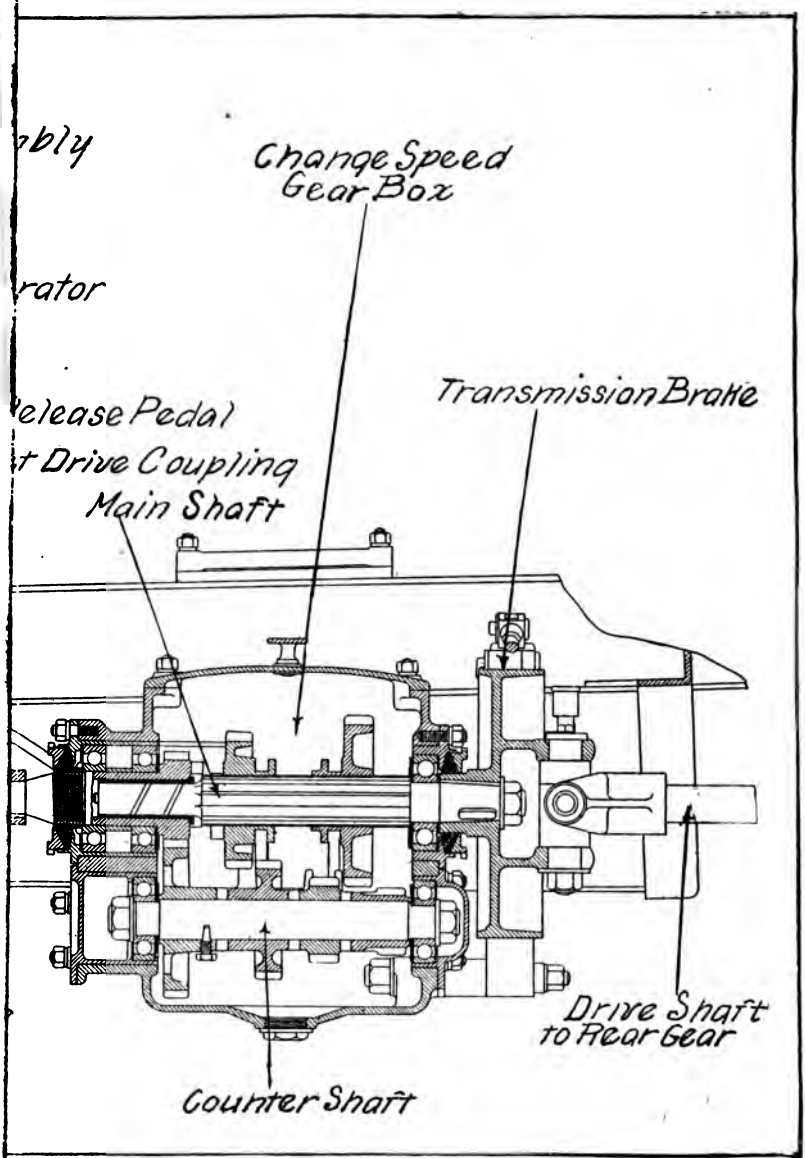
USE OF CLUTCH AND VARIOUS TYPES DESCRIBED

Q. What is the clutch and where is it generally placed?

A. The clutch is used to transmit power from the engine to the gearset and is a form of drive coupling that may be released when it is desired to allow the power generating and energy transmitting members to run independently of each other. A typical power plant, clutch, and gearset assembly is outlined at Fig. 143 with all parts clearly indicated. The power generated by the explosion of the gas against the pistons of the motor imparts a rotary movement to the crankshaft, and from thence to the flywheel which is rigidly connected thereto. The motor flywheel serves as one member of the clutch and is machined with a taper into which the cone or male member of the clutch fits. The cone is held in frictional contact with the flywheel rim by a spring and when the parts are in the positions indicated practically the full power delivered to the engine crankshaft will be transmitted through the clutch cone to the clutch shaft which is joined to the main shaft of the gearset by a positive drive coupling. If the cone is pulled away from the flywheel rim by means of the clutch release pedal provided for the purpose, the engine crankshaft may run independently of the gearset.

Q. Why is a clutch needed with a gas engine and not with a steam or electric motor?

A. A steam or electric motor may be started under load because the real motive power, which is steam or electricity, as the case may be is under pressure in a suitable container and this working medium may be directed to the power plant and sets it in motion against its load. In order to get a start it is possible to supply an excess of



Engine, Clutch and Change Speed Gearset.

power if this is necessary. In a gas engine the power is generated by explosions occurring directly in the cylinders and it is not possible to start an engine of this kind under full load. In order to start the engine, it should be free from the retarding influence of the car, and for this reason, it is necessary to interpose the clutch between the source of power and the point of application to enable the engine to be started independently of the vehicle it propels. Then again it would be inconvenient to be constantly stopping the motor every time one desired to stop the car, so the clutch enables one to stop the car and the motor can be kept in operation until such time it is desired to start again, when the clutch may be re-engaged and the motor power again directed to the traction members.

Q. What is the principle of clutch action?

A. Most clutches operate because of frictional adhesion of various substances under pressure. In some forms the power is transmitted by the actual mechanical interlocking of two members, one which has projecting points and the other which has depressions made to receive the projections of the opposing member. These clutches are known as positive clutches, while those which depend on frictional adhesion are termed "friction clutches." The essential parts of all clutches are the same, consisting of a driving member attached to the source of power, a driven member attached to the power transmission member and suitable means to hold this into engagement when it is desired to transmit the power and separate them when it is necessary for the engine and gearset to run independently of each other.

Q. What are the principal types of friction clutches?

A. Friction clutches may be divided into four main classes: the cone, plate, multiple-disc and band forms.

Q. Describe construction and name important parts of cone clutch.

A. A typical cone-clutch assembly with the main parts clearly indicated is outlined at Fig. 144 and an optional arrangement of parts sometimes used is depicted at Fig. 145. The driving member of the clutch is formed by the motor flywheel, while the driven member is a cone that is held in contact with the tapering inner

periphery by means of a heavy spring connected in such a way that it is restrained from end movement by a suitable means of fastening to the crankshaft. As long as the spring keeps the clutch cone in contact with the flywheel and the spring is permitted to exert its full pressure, the clutch cone and flywheel are firmly locked together to form practically a rigid coupling. When it is desired to release the clutch a shifting yoke carrying clutch release rolls is

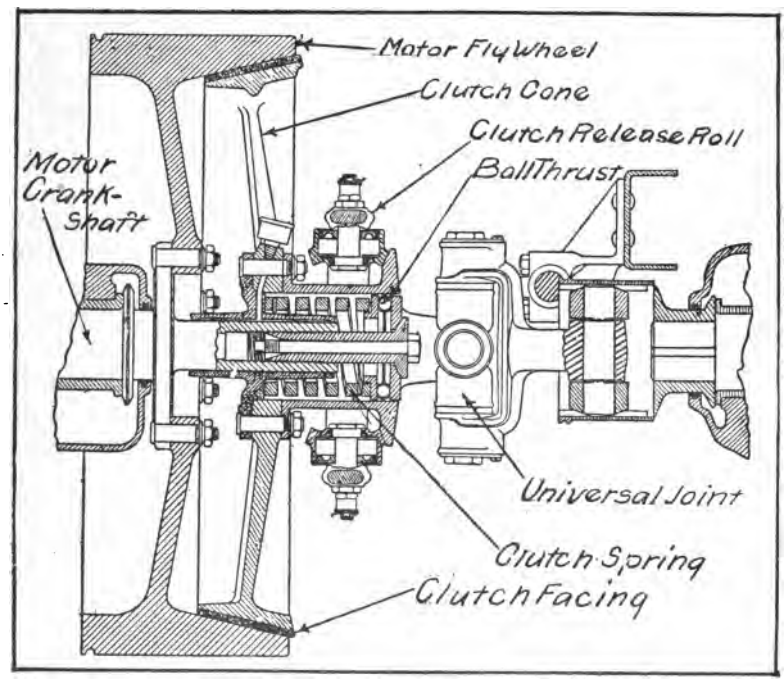


Fig. 144.—Cone Clutch Used on Pope-Hartford Motor Cars.

adapted to bear against an upstanding flange attached to the clutch cone and to pull the cone out of engagement with the motor flywheel by compressing the clutch spring.

The form of cone clutch shown at Fig. 145 is known as the inverted type because the clutch cone is held in contact by a spring pushing the cone away from the flywheel and having an inverted taper so that the more the cone is pushed away from the flywheel

the greater will be its degree of frictional adhesion with the applied ring that serves as a female clutch member. To release a clutch of this type it is necessary to push the cone toward the flywheel, while in the forms shown at Fig. 144 it is necessary to pull the clutch cone away from the flywheel.

Q. What is the female member, and how is it made?

A. The female member of a cone clutch is usually the driving portion and is made of cast iron, either in the form of an applied ring machined with an internal taper, as shown at Fig. 145, or it may be integral with the motor flywheel as is common practice. When the inverted type of clutch is used, it is necessary to bolt the female member in place to the flywheel, as shown at Fig. 145.

Q. What is the cone made of?

A. The clutch cone is usually a light aluminum casting or a sheet steel stamping.

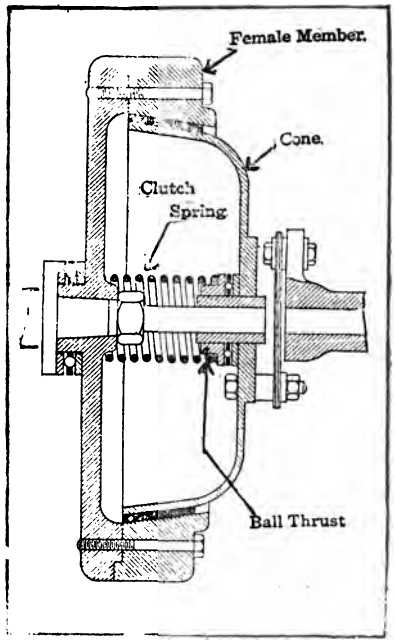


Fig. 145.—Simple Inverted Cone Clutch of Foreign Design.

Q. What is the angle of the cone taper and why?

A. The usual angle employed for clutch cone is twelve and one-half degrees and this is used because it is the least that can be utilized and have a clutch that will release promptly and yet not require excessive spring pressure to keep the parts in contact when transmitting power. More gradual tapers are apt to produce wedging and make it difficult to release the clutch promptly, while more abrupt tapers will cause the clutch to slip, unless the parts are held together by considerable spring pressure.

Q. Why is it desirable to make the cone as light as possible?

A. The clutch cone is usually made light so that it will not spin

or rotate appreciably after it has been released from the driving member. The heavier the clutch cone, the greater will be its inertia or tendency to revolve, due to the power stored in its rim.

Q. What materials are used to face the clutch cone with?

A. The clutch cone is usually faced with a good grade of oak tanned sole leather though in some cases asbestos fabrics have been used with success. In some constructions the cone is of metal, studded with cork inserts, though as a rule the cone is faced with leather even if cork inserts are used. Materials are used for facings that are not likely to be affected by oil or heat and that have a high coefficient of friction with cast iron of which the female member is invariably composed.

Q. What does "coefficient of friction" mean?

A. The "coefficient of friction" is a term used to indicate the amount of frictional adhesion various materials have for each other under similar conditions of pressure.

Q. Name the "coefficient of friction" of various surfaces in contact.

A. A table of friction coefficient of various materials compiled from tests made by the Cork Insert Co. follows:

MATERIAL	COEFFICIENT
Metal and Cork on dry metal	0.35
Leather and Cork on oily metal	0.32
Fiber and Cork on oily metal	....
Fiber on dry metal	0.27
Fiber on oily metal	0.10
Leather on dry metal	0.23
Leather on oily metal	0.15
Charred leather on oily metal	0.08
Metal against dry metal	0.15
Metal on oily metal	0.07

The coefficient will vary with condition of the contacting surface. Smooth and hard surfaces offer less resistance than rough and yielding ones. In metal to metal clutches different materials are usually employed for the opposing surfaces such as bronze and steel

in multiple disc clutches or cast iron or bronze and steel in three plate types. A coefficient of friction of 0.10 means that the adhesion between the surfaces will be 10% of the total pressure producing frictional contact. Therefore, a combination leather and cork friction facing acting against dry cast iron, as in a cone clutch, and having a coefficient of 0.35 will adhere to the member against which it contacts with a force equal to about ⅓ of that keeping the surfaces in contact.

Q. How is clutch cone kept in contact with female member?

A. The clutch cone in practically all cases is held in engagement with the female member by the pressure of one or more coil springs. In some constructions the clutch cone is brought into engagement by means of levers actuated by some member that can be locked in place to hold the parts in contact until released.

Q. What is the function of the ball thrust bearing?

A. As will be observed by referring to Figs. 143 to 145 in no case is the spring pressure applied directly to the clutch cone and a ball thrust bearing is always interposed to take the spring thrust against the cone. This is used in order to permit the parts to operate independently of each other when the clutch cone is moved so the spring is compressed. The ball thrust bearing has so little friction that the full spring pressure may be exerted against it without causing rotation of the cone when that member is out of engagement with the flywheel rim. If no ball thrust bearing was used when the clutch cone was pushed away from the female member, the spring in contact with the driving member would tend to impart its rotary motion to the clutch cone and keep it turning when it is desirable to have it stop when released.

Q. What are the advantages of the cone clutch?

A. The cone clutch is a very simple form that is easy to operate and understand. When properly designed it will transmit the entire power of the motor to which it is applied without slipping and it can be made to release promptly and to engage gradually if desired.

Q. What is the main disadvantage of a cone clutch?

A. Owing to the mass of the clutch cone and its leather facing

there is a tendency for the cone to continue to rotate when released from driving engagement with the flywheel. The rim of even the lightest cone and its leather facing have appreciable weight, and while this is not much it is carried at a sufficiently large radius from the center so the cone has considerable momentum and acts, to some extent, as a flywheel. This continued rotation is called "spinning" and is objectionable, because it makes gear shifting difficult.

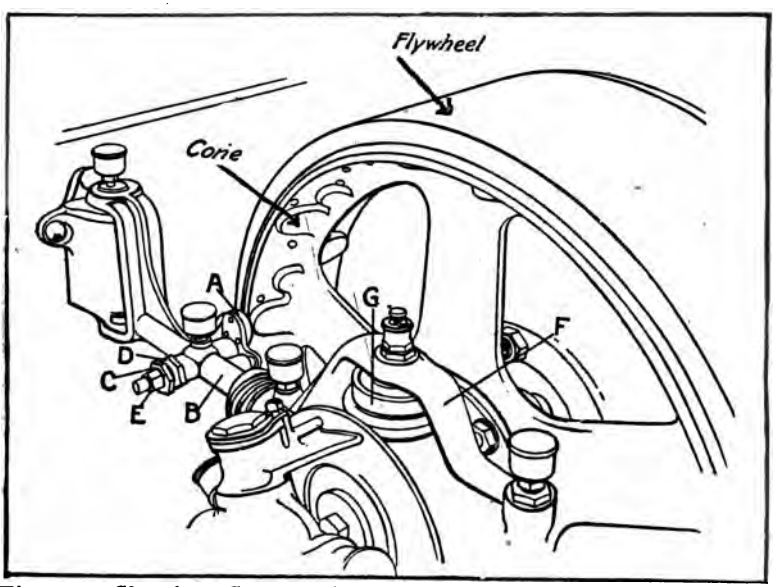


Fig. 146.—Showing Construction of Clutch Cone Brake Used on Pope-Hartford Cars.

Q. How is "spinning" prevented?

A. Continued rotation of the clutch cone is easily prevented by applying some form of braking member which will come in contact with the revolving cone after it has been pulled clear of the flywheel. A simple clutch brake is shown at Fig. 146. The friction pad *A* is carried by the clutch shifter yoke *B* in such a way that it comes in contact with the clutch cone only when this has been withdrawn a certain distance by the yoke *F* and the rolls *G*, as previously described. Suitable adjustments are provided at *C*, *D*, and *E*, so

the friction pad may be brought into engagement with the cone at any time that is desirable and in order to compensate for wear or other depreciation of the friction pad *A*.

Q. Describe three plate clutch and explain its action.

A. Two forms of three plate clutches are in general use; that outlined at Fig. 147 uses a large number of small springs to produce the pressure required to keep the parts in contact, while the form

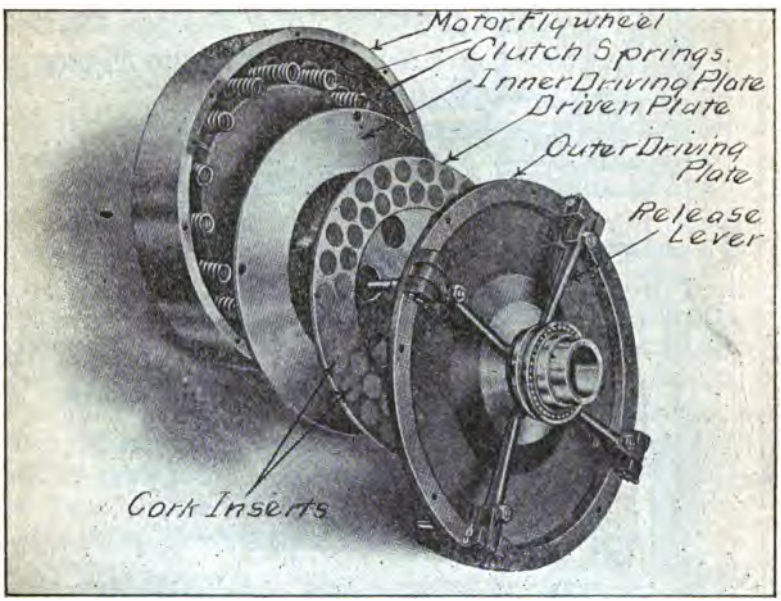


Fig. 147.—Principal Parts of Knox Three-Plate Clutch.

depicted at Fig. 148 utilizes one main spring. A three plate clutch is so called because the central driven member serving to drive the clutch shaft connected to the gearset is sandwiched in between driving plates carried by the flywheel. In the Knox clutch shown at Fig. 147 the clamping pressure to keep the driving plates in firm contact with the driven plate is obtained from a series of clutch springs carried near the flywheel rim. As the total pressure exerted by these springs is somewhere in the neighborhood of a thousand

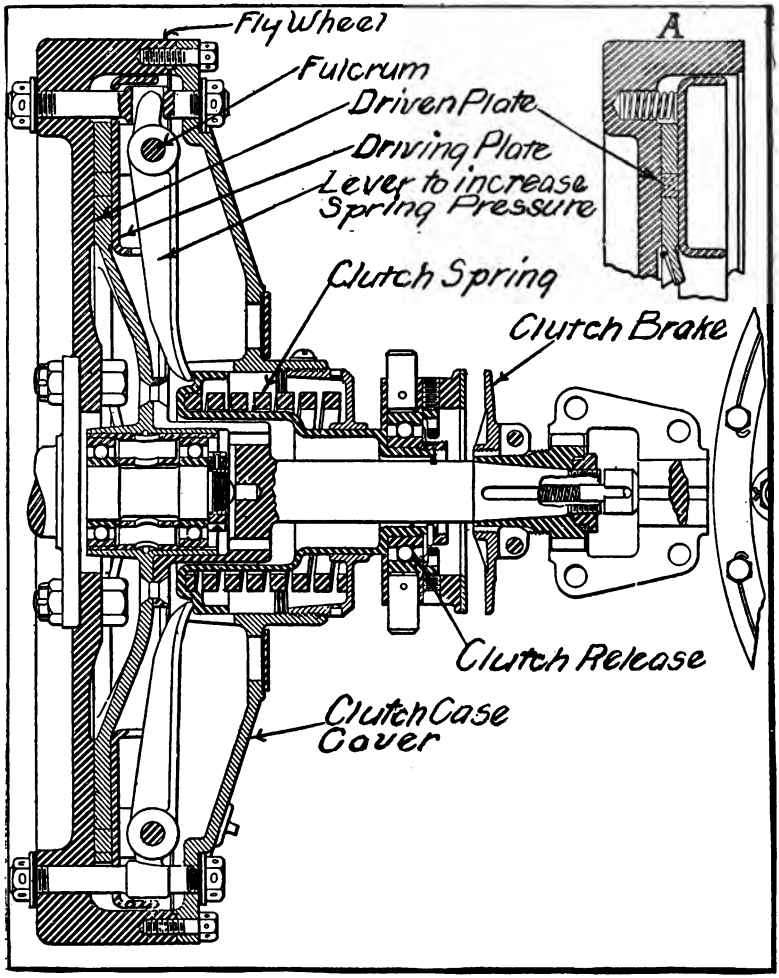


Fig. 148.—Showing Construction of Three-Plate Clutch in Which Spring Pressure is Augmented by Levers to Increase Adhesion Between Clutch Members.

pounds it is necessary to provide some form of leverage so the inner and outer driving plates may be separated without undue exertion on the part of the operator. As will be evident in the clutch shown at Fig. 147 any pressure exerted against the long arms of the levers

will be multiplied many times and comparatively little effort is needed on the part of the operator to push the levers in toward the flywheel and transfer the multiplied pressure through the pins which extend through the outer driving plate and into the inner driving plate to compress the springs and thus relieve the driven plate from contact with either of the driving plates between which it is normally held.

In the clutch outlined at Fig. 148 the spring pressure is made light enough so that it may be compressed without difficulty by the operator but its effective pressure or that brought to bear against the outer driving plate is multiplied about six times. In this clutch the flywheel web is faced off to serve as one driving surface and a clutch brake is provided so spinning of the driven plate may be prevented when the clutch release collar is pushed back against the revolving disc keyed to the clutch shaft. Whereas the average spring pressure of a cone clutch is seldom over three hundred pounds that of a three plate form is much higher as greater pressure is needed to hold flat surfaces in engagement than is required to drive through a male and female cone combination. The three plate clutch has an important advantage in that it releases positively and will engage gradually. Its main defect is that it requires a large diameter driven plate which brings up the same objection offered against the cone clutch, that of spinning, which however can be taken care of in the same manner.

Q. What materials are used in three plate clutches?

A. The two driving plates which are carried by the flywheel are either of steel or cast iron with smoothly finished surfaces while the driven member may be either of cast iron or bronze studded with a large number of cork inserts, which increase the frictional adhesion and make for smooth engagement. Either of the three plate clutches described may be run in an oil bath as the entire clutch mechanism is fully protected by the casing formed in the flywheel interior by the application of a suitable cover bolted to the flywheel rim. In the Knox clutch the flywheel cover serves as one of the driving members but in that at Fig. 148 the cover is a separate member serving only to enclose the clutch parts. The inset at *A*, Fig. 148, shows a method of insuring prompt release of the driven

plates, by means of small coil springs which are placed between the two driving plates and which serve to push these out of engagement with the driven plate as soon as the main spring pressure is released.

Q. What is a five plate clutch?

A. A typical five plate clutch is outlined at Fig. 149. This is

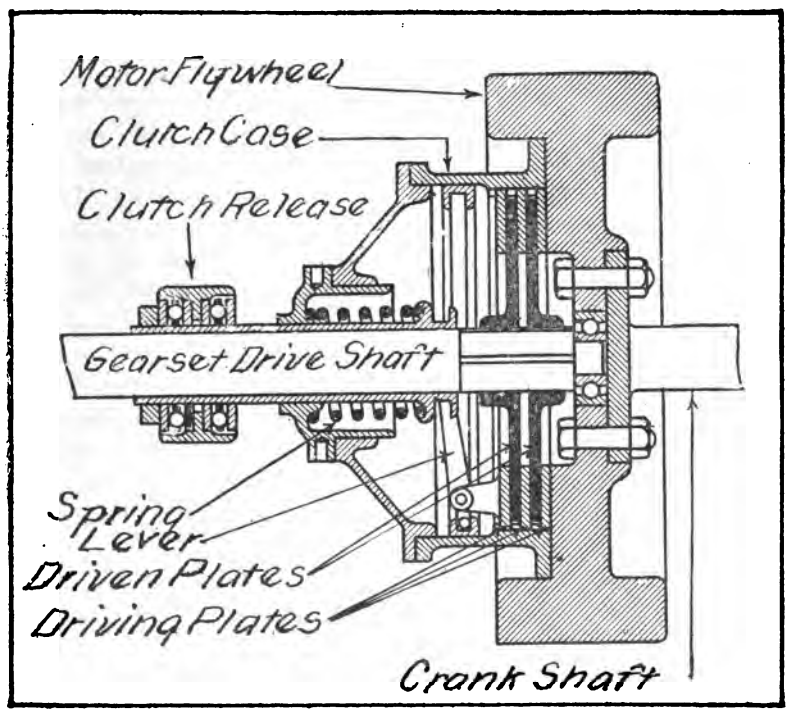


Fig. 149.—Simple Form of Five-Plate Clutch.

practically the same in construction and operation as the three plate pattern shown at Fig. 148 with the exception that two driven plates and three driving plates are used. A five plate clutch offers more surface than a three plate type and may be made somewhat smaller in diameter and use less spring pressure if employed to transmit the same power.

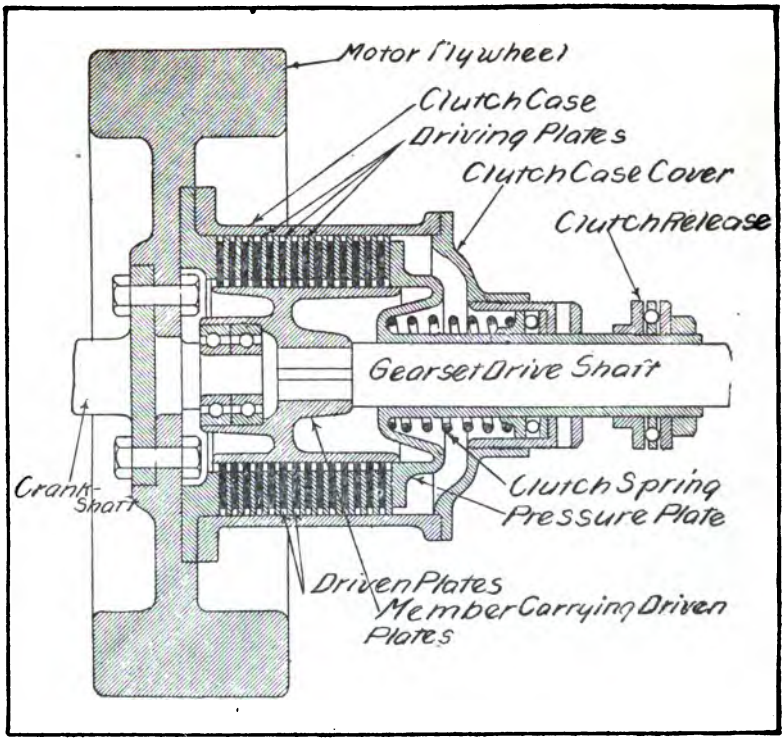


Fig. 150.—Sectional View of Multiple Disc Clutch Designed to Run in Oil.

Q. What is the multiple disc clutch?

A. Multiple disc clutches, one of which is shown in section at Fig. 150 and another form with all parts disconnected to show the arrangement at Fig. 151, is a plate clutch in which small diameter discs are employed instead of the larger diameter plates used in the three and five plate forms. In general principle of operation the multiple disc is similar to the other plate forms and the reduction in diameter is compensated for by using a larger number of surfaces in contact. A series of driving plates are carried by and turn with a casing member attached to the flywheel, while a slightly smaller number of driven plates are carried by a central member which is independent of the flywheel when the clutch is released and which is joined to the gearset drive shaft. The discs are kept in contact

by pressure of a coil spring against a pressure plate, which presses against the outer driving plate and holds the entire disc assembly into firm engagement. Obviously as long as the discs are held together the engine power must be transmitted from the clutch case attached to the flywheel through the disc assembly to the central member carrying the driven plate and attached to the gearset drive shaft. To release the multiple disc clutch the spring is compressed enough to allow the driven plates to turn freely between the driving plates.

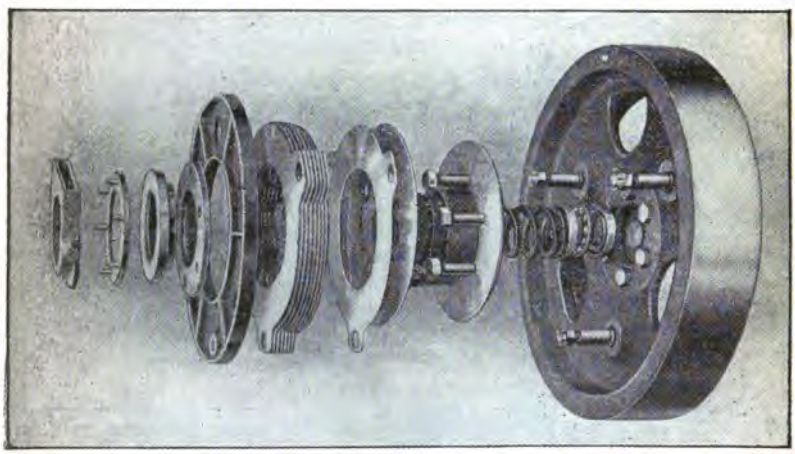


Fig. 151.—Multiple Disc Clutch Parts Shown in the Order They are Removed from Flywheel in Taking Down Assembly.

Q. How many types of multiple disc clutch are used.

A. Multiple disc clutches may be of the all metal disc type, which are designed to run in a bath of lubricant, or of the dry plate pattern where one set of plates, usually the driven members, are faced with some material designed to have greater frictional qualities than metal surfaces when run without lubrication. One form of multiple disc clutch, that shown at Fig. 152, differs from the conventional form in that the clutch discs are stamped out so the surfaces in contact are in the form of a cone. In general construction this clutch follows conventional design.

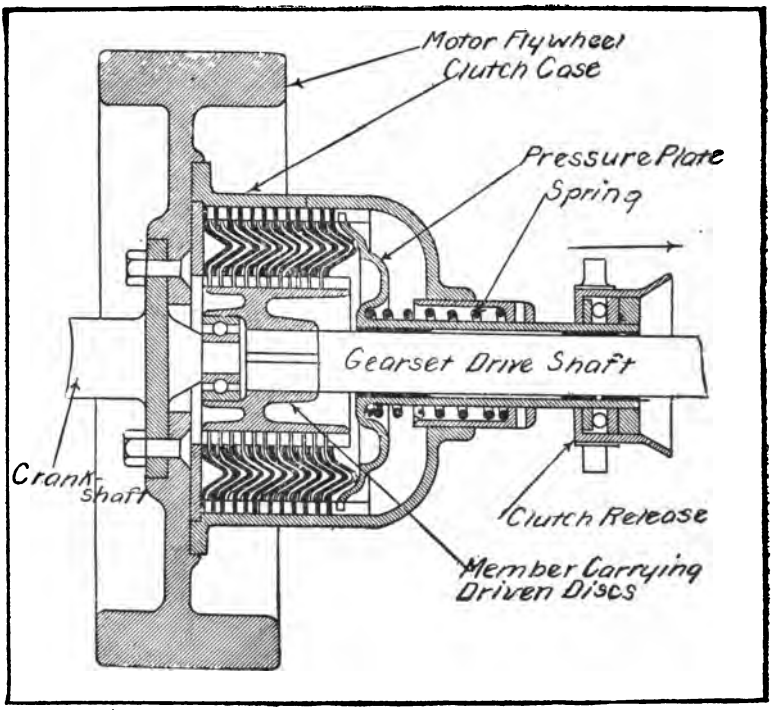


Fig. 152.—Sectional View of Hele-Shaw Multiple Disc Clutch and Efficient English Design.

Q. Describe advantages of multiple disc clutches.

A. The most important advantage of a multiple disc clutch is that it is small and compact, and its construction such that very gradual engagement is attained. Owing to the large number of friction surfaces and the presence of a film of oil between each pair of surfaces it is practically impossible for a clutch of this pattern to engage harshly, as the spring pressure must first squeeze out the film of oil between each pair of plates before the friction adhesion is great enough to drive positively. Owing to the small size and relatively light weight of the driven plate assembly this is not liable to spin as is the heavier cone or three plate clutches, but to offset this advantage there is a liability of dragging, due to the adhesive properties of the oil film present between the plates.

Q. What materials are used in multiple disc clutches?

A. The discs of multiple disc clutches designed to operate in an oil bath are usually thin stampings from saw steel sheets which are hardened and ground to a true surface. In some clutches the plates are all steel and in other forms the driving members are of steel while the driven plates are stamped from phosphor bronze sheets. In dry plate clutches the driven plates, which are faced with Raybestos or other suitable friction material, are steel stampings while the driving plates may be either steel stampings or cast iron plates. In some dry plate forms the driving members are cast iron while the driven plates are of bronze studded with cork inserts.

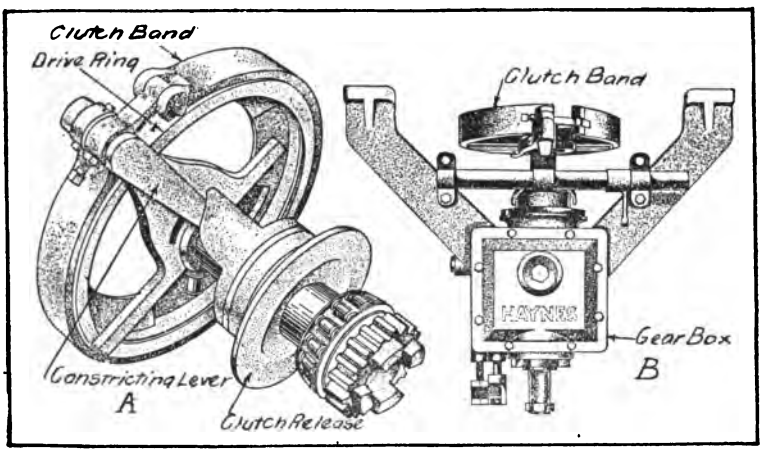


Fig. 153.—Construction and Application of Haynes Constricting Band Clutch.

Q. What is a positive clutch?

A. The forms of clutches in which projecting members fit into depressions in the coacting part and which act as positive mechanical locks are termed "positive clutches."

Q. Are positive clutches ever used alone?

A. Positive clutches are always used in connection with a master clutch of the friction type because they would be much too harsh in action and impose considerable strain on the power plant and transmission parts if used alone.

Q. What types of band clutches have been used and how do they operate?

A. Band clutches have been made in two forms, the internal expanding and external constricting types. The former is seldom used at the present time because it is a very difficult type to balance properly and to keep in proper adjustment. The external band form outlined at Fig. 153 is used on the Haynes car and it consists of a metal clutch band adapted to constrict around a drive ring attached to the flywheel. The band is tightened by means of a constricting lever operated by a cam or inclined plane member pressed forward by a coil spring. In operation the external band, which is attached to the gearset drive shaft, clamps tightly around the drive ring while the internal band form spreads out against the internal periphery of a similar drive ring integral with the flywheel.

Q. What are the essential requirements of clutches and which type meets most of the requirements?

A. A clutch must be simple to construct, apply and operate and it must be capable of transmitting the maximum engine power in a positive manner. It must release promptly and yet it should not engage too harshly. It should be of such form that any wear occurring will be automatically taken up and it should be easy to restore the frictional materials when these deteriorate. Practically all of these requirements are met by the friction clutch in any of its forms and the cone form owing to its simplicity and strength of parts is the most favored of all clutch types.

LESSON SIXTEEN

THE FRICTION TRANSMISSION

Q. Why is change speed gearing necessary on gasoline automobiles?

A. The gasoline engine develops power in direct proportion to its speed up to a certain point and it will slow down whenever an overload is applied. More power is needed to climb hills than is used to propel the car on the level and if the gasoline engine was directly attached to the rear wheel with a definite unvariable ratio it would not be possible to climb hills unless this reduction of speed between engine shaft and rear wheels was very low. When conditions were favorable, such as when the resistance to motion was slight, as on smooth level highways, the low reduction provided would be too slow and the car speed would be limited to that permitted by the gear ratio. At the other hand if the gear ratio was higher to permit more speed under favorable conditions it would be too high for hill climbing or propelling the car over rough road surfaces. In order to enable the power plant to develop its full power it is customary to provide some form of change speed gearing to permit of altering the ratio of drive between the engine and the rear wheels to suit road conditions. The usual ratio on the direct drive or highest speed varies from three to one to five to one in pleasure cars and may go as high as ten to one on heavy vehicles. This means that the engine crankshaft will make from three to ten turns while the rear wheels are revolving once. As a gasoline engine is not reversible it is customary to incorporate gearing that will permit of reversing the car motion in the change speed gear set.

Q. Why are electric and steam automobiles without change speed gearing?

A. It has been previously explained that steam engines or elec-

tric motors, which derive their power from stored energy, are capable of operating at an overload and while their speed of rotation may be reduced it is possible to obtain the rated horse-power by admitting more steam to the cylinder or more current from the storage battery to the windings of the motor. Either the steam engine or the electric motor is capable of being reversed; by changing the direction of flow of the energizing agent in the case of the electric motor, by a simple shifting of valves in the steam engine. This flexibility of steam and electric power enables the manufacturer of these cars to dispense with change speed or reverse gearing.

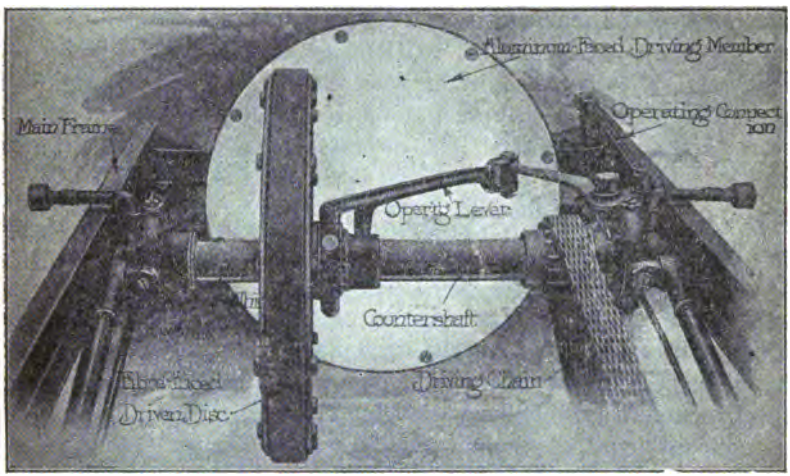


Fig. 154.—The Lambert Friction Disc Combined Clutching and Speed Changing Mechanism.

Q. What is the simplest method of obtaining speed reduction?

A. The simplest method of obtaining speed changes and one that will provide a large range of speed variations is by using friction discs or, as they are sometimes called, friction gearing.

Q. What is friction gearing?

A. Friction gearing in its simplest form consists of bringing two wheels into frictional contact with each other and holding them in

contact with sufficient pressure so the driving wheel will cause the member against which it bears to rotate as well. The simplest form of friction gear is the face friction drive.

Q. Describe parts of face friction gearing.

A. A typical face friction gear that has given good results in practice is shown at Fig. 154 and all parts are clearly depicted in the illustration. The engine drives an aluminum face driving member with its face at right angles to the engine crankshaft. The driven member is a fiber faced wheel carried by a cross shaft which extends across the frame and which is carried in suitable bearings attached to the frame sides. This countershaft carries the driving sprocket and is parallel to the face of the aluminum driving member. The fiber face driven wheel can be moved back and forth across the face of the driving member by suitable leverage connected with the control handle. The direction of countershaft rotation and its speed relative to the engine crankshaft is determined by the position of the fiber face driven wheel relative to the center of the driving member.

Q. How is clutching effect obtained?

A. The aluminum face driving member is capable of being brought into contact with the driven wheel or moved away from it at the will of the operator. The amount of pressure between the two members may be varied by a pedal. When the discs are brought into contact the drive is taken up and power is transmitted from one member to the other and as soon as the discs are separated the drive will be interrupted. The operator can control the amount of pressure and consequently the amount of drive to a nicety and consequently a gradual power application may be obtained.

Q. How is the car reversed?

A. The process of reversing is easily accomplished by pushing the fiber face driven wheel over to one side of center of the aluminum face driving member. As indicated in Fig. 154 the driven wheel is placed to the left of center, which is a position giving forward drive. If moved toward the right of center or toward the driving chain sprocket the countershaft will revolve in an opposite direction to the way it rotates when the driven disc is in forward drive

position and as a result the direction of rotation of the rear wheels would be reversed and the car would be driven backward.

Q. How are speed changes effected?

A. The aluminum face driving member and the fiber face driven wheel contacting with it are practically of the same size and when the driven member is moved to its extreme position at the left of the countershaft that member is turning at practically the same speed as the engine crankshaft. As the fiber face driven disc is moved toward the center of the driving member the speed of the countershaft decreases until center is reached where the shaft will not turn in either direction. The nearer the center of the disc the fibre faced wheel bears the greater the reduction of speed between the engine crankshaft and the countershaft. Assume, for example, that both driving and driven members were twenty-four inches in diameter. If the driven disc is brought to bear against the aluminum driving member at a point two inches from the center it would be just as though a four inch diameter wheel was employed to turn one twenty-four inches in diameter. The result would be that the engine shaft would turn six times as fast as the countershaft If the driven disc was moved so it contacted with a point on the driving member at a radius of four inches from center it would be the same as though the twenty-four inch driven disc was turned by a wheel eight inches in diameter and the countershaft would turn at one-third the speed of the engine crankshaft.

Q. What material is used for the driving member?

A. The driving member is usually a cast iron flywheel, which is faced with an aluminum alloy or copper-aluminum alloy plate attached to the driving member casting by means of countersunk head machine screws.

Q. What material is used for the driven member?

A. The driven member is usually a cast iron wheel provided with flanges between which a ring of straw board fiber is clamped, the metal portions of the wheel serving merely as a carrier for the fiber driving ring. Experiments have demonstrated that the combination of aluminum and strawboard fiber has a higher coefficient

of friction or greater adhesion and endurance than any other common materials.

Q. How long does a friction fiber ring last?

A. The life of a friction fiber ring depends upon the amount of pressure with which the driving and driven members are kept in contact. Under average conditions a fiber ring will last several thousand miles, but as they are cheap and easily renewed their

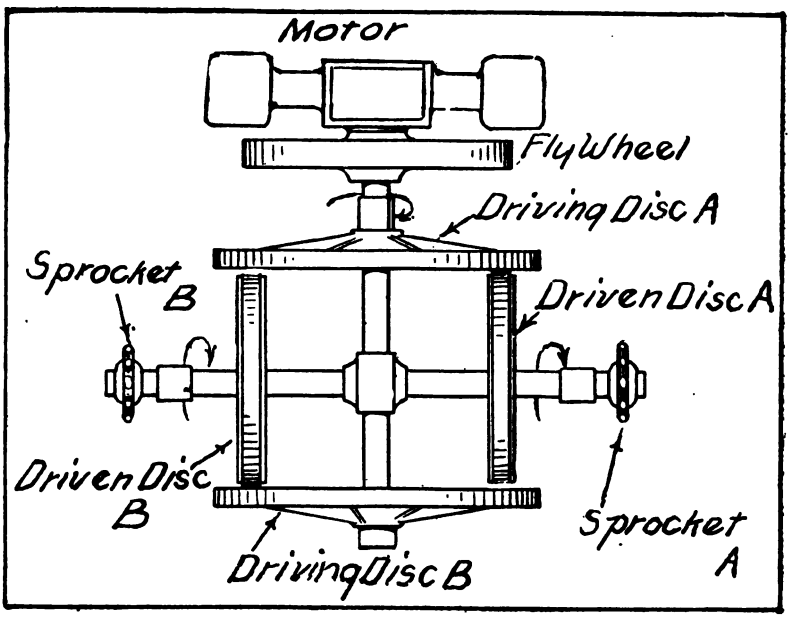


Fig. 155.—Friction Drive Set Utilizing Double Disc Principle.

replacement is not considered a disadvantage of sufficient moment to condemn that form of drive.

Q. What are the limitations of friction gearing?

A. As a rule, friction gearing will not transmit power as efficiently or as positively as the geared transmission on account of the loss of power due to slipping between the discs. The friction disc type of transmission is not suitable for transmitting large power unless it is made very bulky and experience has demonstrated that

it is not as reliable for general application as toothed forms of gears.

Q. What advantages does friction gearing offer?

A. Friction gearing offers important advantages in that it is easily operated by the novice, is simple in construction and not liable to injury by careless operation. The face friction type offers an infinite number of drive ratios and may be so constructed as to give just as many ratios in one direction as in the other. As speed

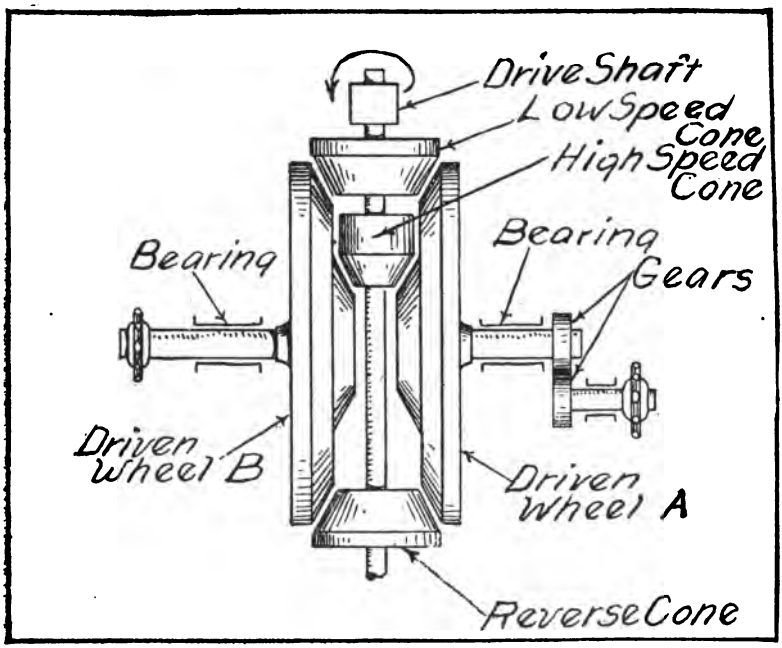


Fig. 156.—Friction Driving Gearing of Bevel Face Type Giving Two Speeds Forward and a Reverse Ratio.

changing and clutching functions are combined in one device, the principles of operation may be easily understood by people without previous mechanical experience.

Q. How can friction gearing be used for transmitting large amounts of power?

A. Friction gears have been devised that are capable of trans-

mitting more power than the simple face friction gearing previously described by using more discs in order to obtain a greater driving surface. The form shown at Fig. 155 utilizes two driving discs *A* and *B* driven by the engine and two driven discs *A* and *B* attached to a countershaft divided in the center and supported by a bearing so that it virtually becomes two countershafts. Driven disc A which contacts with the driving disc *A* only turns sprocket *A* while driven disc *B* contacts with driving disc *B* only and drives sprocket *B*. The various speed ratios are obtained by moving the driven discs simultaneously, the principle of speed reduction being the same as with simple face gearing. Reverse motion is provided by auxiliary gearing.

The friction gearing shown at Fig. 156 is a form which uses beveled driving and driven members but this method of construction does not provide an infinitely variable number of speed reductions. The form shown gives only two forward speeds and a reverse motion. Three cones are mounted on the driven shaft, which is turned by the engine, each of these being actuated by independent means so that they may be brought into action with corresponding faces of the driven wheels *A* and *B*. When the low speed cone is brought into action with the larger beveled face the greatest reduction of speed is obtained. When this is released from contact and the high speed cone is pushed into engagement with the small diameter beveled faces the highest ratio of drive is provided. The reverse cone is brought in contact with the large diameter bevel surface and driven wheels *A* and *B* reverse the direction of motion of the drive sprockets which transmit power to the wheels by chain connection. It will be observed that driven wheel *A* is not attached to the sprocket as is driven wheel *B* but that the sprocket is turned by means of a pair of spur gears which reverse the motion of driven wheel *A* and cause both sprockets to turn in the same direction.

Q. Has friction drive ever been applied directly to rear axle?

A. A form of friction drive in which the change speed and driving mechanism has been applied directly to a rear axle is shown at Fig. 157. The driving disc *A* in this case is the fiber faced member and slides on the squared shaft *H* which is driven from the engine

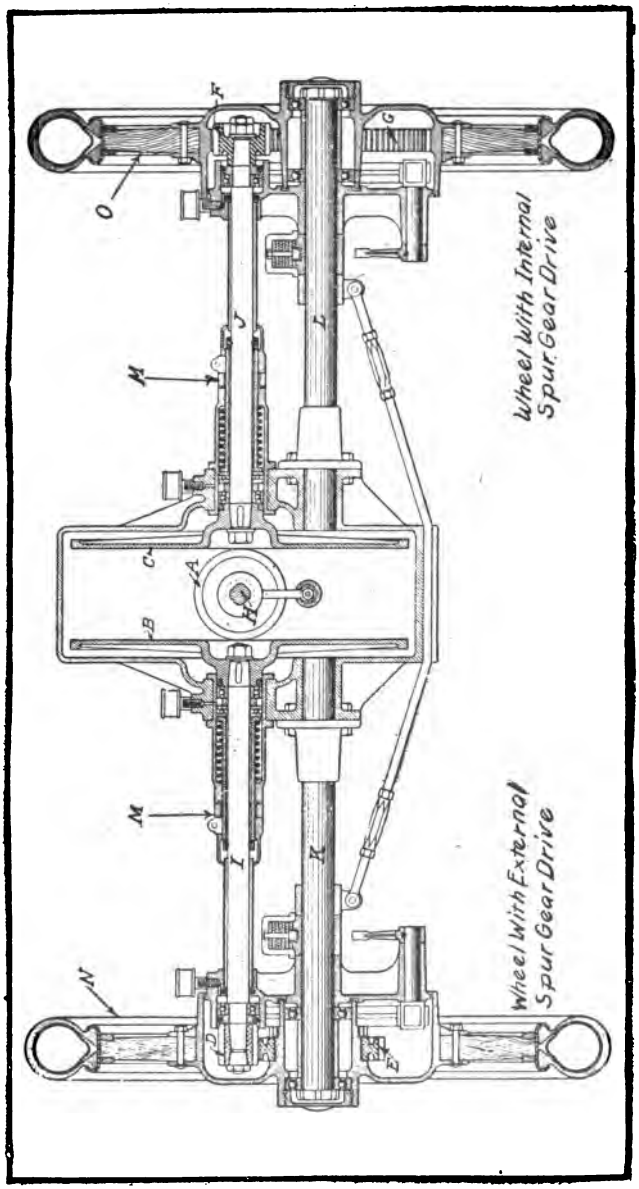


Fig. 157.—Showing One Method of Applying Friction Drive Directly to Rear Axle.

by the usual form of propeller shaft. The driven discs *B* and *C* are adapted to be brought out of engagement with the driving member *A* by means of the actuating collars *M* connected to a suitable pedal. The driven wheels *B* and *C* are normally kept in engagement with the driving member *A* by means of springs surrounding the axles *I* and *J* and transmitting their pressure through ball thrust bearings against the hubs of the driven wheels *B* and *C*. Wheel *B* is attached to axle *I* by means of a key and drives the spur pinion *D* which meshes with the spur gear *E* attached to the wheel hub *N* which rotates on the stationary axle *K*. The driven wheel *C* is attached to axle *J* in a similar manner and rotates the spur pinion *F* which meshes with an internal spur gear *G* attached to the hub of the wheel *O*. This wheel revolves on the fixed axle *L*. It will be noted that driven members *B* and *C* are provided with a recess at their center and when the wheel *A* is moved into this recess it is out of contact with the driven members and can turn without producing movement of wheels *B* and *C* and of the road wheels *N* and *O* to which they are connected. In this case the higher speed ratios are obtained when the disc or driving wheel *A* is nearest the center of the effective driving face of *B* and *C*. As the wheel *A* is moved toward the outer peripheries of the driven members the speed ratio becomes lower on account of the difference in size between the driving wheel *A* and the diameter of the circle on wheels *B* and *C* with which it contacts. The reason that an internal spur gear drive is used at wheel *O* instead of the external spur gear arrangement used to turn wheel *M* is that this is necessary to insure that both wheels will turn in the same direction, on account of the wheels *B* and *C* being at opposite sides of the driving member *A*. As is true of the simple form of face friction gearing outlined at Fig. 154 a reverse motion may be obtained by moving the disc *A* along the drive shaft *H* to the other side of center of the driven wheels *B* and *C*.

LESSON SEVENTEEN

THE INDIVIDUAL CLUTCH CHANGE SPEED GEAR

Q. What is an individual clutch change speed gear?

A. An individual clutch change speed gear is a form in which the various changes of speed are effected simultaneously with the engaging of some form of clutch that brings that gear ratio into action.

Q. What are its advantages?

A. In most forms of individual clutch gearsets the various gears through which the different speed ratios are obtained are always in mesh and the construction is such that it is not possible to injure the gear teeth when changing from one speed to another.

Q. What are the principal types of individual clutch gears?

A. There are two main forms of individual clutch gears, the simplest being the planetary or epicyclic gear, the other form resembling a sliding gear transmission in general outline and arrangement of parts but having the gears always in mesh. In the planetary system the speed desired is obtained by manipulating clutch bands, a different clutch being provided for each speed. In the positive clutch type a separate jaw clutch is provided for each speed ratio but the entire gearset is controlled by a master clutch, which is common to all speed ratios, as it serves to couple the engine and gearset shaft together.

Q. What is the planetary gear and why is it so designated?

A. A typical planetary gear is outlined at Fig. 158 and it is so called because the change speed gears revolve around a center gear attached to the main shaft, the motion of the gearing resembling that of the planets around the sun. In the form outlined the gear *D*, which is attached to the central shaft, is termed the "sun" gear

while the gear assembly comprised of members *B*, *C* and *E* are termed "planet" gears.

Q. Describe the construction of a typical planetary gearset.

A In the form shown at Fig. 158, the shaft *K* is attached to the flywheel of the engine by means of the flange machined integral with it. This serves as the main driving member for the gearset and the gear *D* and the high speed spider which carries the clutch plates *J* are keyed to this shaft so they must turn with it. The change speed gearing is contained in a casing which has bushings

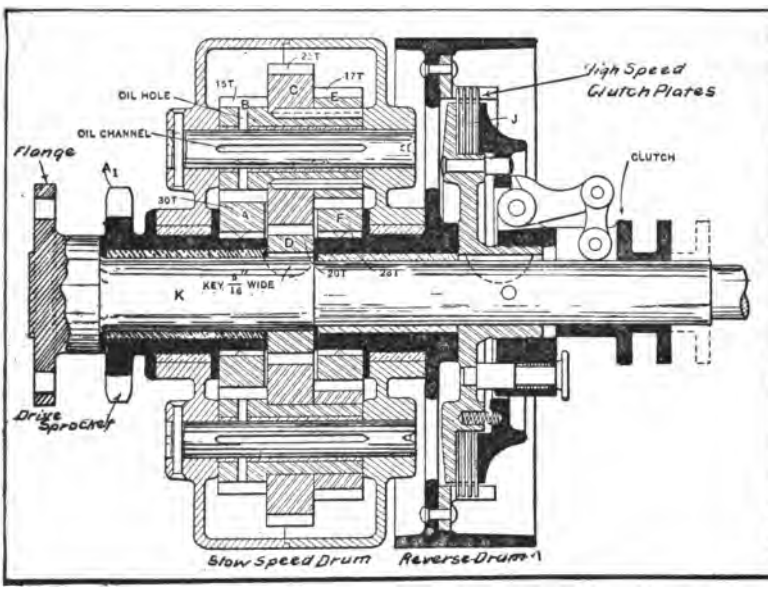


Fig. 158.—Parts of All Spur Gear Two-Speed and Reverse Planetary Gearset.

so that it can turn on the sleeves to which the sprocket *A*-1 and gear *F* are attached and these sleeves are in turn provided with an internal bearing so they may revolve independently of the driving shaft *K* if necessary. The planet gears, *B*, *C*, and *E* are joined together to form an assembly which turns on a suitable shaft parallel to the shaft and spaced on a circle whose radius is equal to the distance between the centers of the planet gear pin and the main

shaft. Gear *A* is keyed to the same sleeve to which the drive sprocket *A*-1 is attached, while gear *F* is keyed to a sleeve to which the reverse drum is fastened. Suitable clutch plates serve to establish connection between the high speed clutch plate carrier which is keyed to the engine shaft and the reverse drum to which gear *F* is secured. Brake bands are provided, capable of arresting motion of either the low speed drum which also acts as the gear casing or the reverse drum to which the driven direct drive clutch plates are attached. These bands are not shown in the illustration.

To obtain a low speed the slow speed drum is kept from revolving by clutching it and the drive is from the gear *D* to the planet gears *C* which turn in the opposite direction and from the gear *B* of the planet gear assembly to the gear *A* which is keyed to and must turn with the drive sprocket *A*-1. As there is a difference in size between gears *D* and *C*, gear *C* turns slower than gear *D*, and as gear *B* has but half the number of teeth of the gear *A* the sprocket *A*-1 is turned at half the speed of gear *B* and a little less than half the speed of gear *D* and in the same direction. If the reverse drum is kept from rotating the gear *F* attached to it is also held stationary. The result is that the gear *D* drives the gear *C* just as when the slow speed drum was held, but as gear *E* cannot turn without running around the fixed gear *F* the motion of gear *A* which is attached to the sprocket *A*-1 is reverse to that of the central shaft.

If the two brakes or clutches are held out of contact with the slow speed and reverse drums and the high speed clutch plates are pushed together by the action of the clutch dogs and toggle the reverse drum is firmly locked to shaft *K*. As gear *D* cannot produce movement of the planetary gear assembly *B*, *C* and *E* without causing the reverse drum to rotate the entire assembly is locked together as a unit and the sprocket *A*-1 turns at the same speed as the shaft *K* and in the same direction.

Obviously, only one clutch can be engaged at a time. When the slow speed drum is held from rotation, the reverse drum must be free to turn and *vice versa*. When the high speed clutch is engaged both slow speed and reverse drums must be capable of turning. Another form of planetary gearset has received some appli-

cation in which internal spur gears are used and a separate set of pinions employed for low or reverse ratios.

Q. How many speeds are provided in the usual form of planetary gear?

A. Planetary gears, as a rule, have two forward speeds and a reverse. It is possible to make a planetary gear that will provide three forward speeds but these are usually so complicated and require so much gearing that they are not as practical as the less costly sliding gear forms.

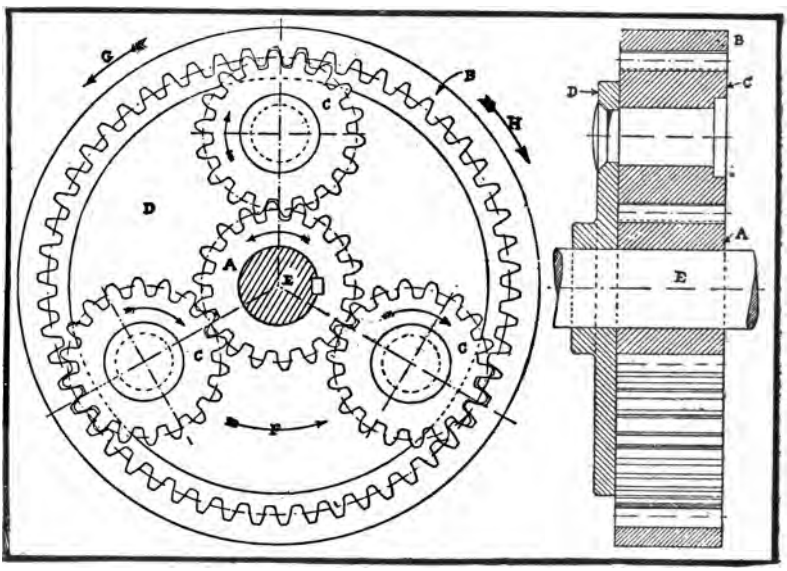


Fig. 159.—Outlining Action of Planetary Gearing When Internal Gear is Employed.

Q. Describe action of slow speed gearing when an internal gear is used in the planetary system.

A. In order to show clearly the method of operation of the other form of planetary gearing a section through the slow speed gearset is shown at Fig. 159. In this the main driving gear *A* is keyed to the engine shaft extension *E* and must turn with it. The planetary pinions *C* are carried on studs attached to the plate *D*, which is

free to rotate around the shaft *E*. The internal gear *B* is in mesh with the planetary pinions *C*. This form of gear assembly can be used for either low or reverse speed depending upon whether the plate *D* or the internal gear *B* is kept from rotating. If the internal gear *B* is kept from turning the drive is taken from the plate *D*. If the plate *D* is kept from turning the driving sprocket is attached to internal gear *B*.

Considering first the action of this assembly to provide a slow speed ratio, let us assume that the internal gear *B* is provided with a brake band to hold it stationary and the plate *D* is in rigid connection with the drive sprocket or shaft which turns the rear wheels. If the engine shaft *E* is turning in the direction of the arrow, gear *A* must turn in the same direction. If the internal gear *B* is kept from rotating the planetary pinions *C* must not only turn around on their supporting stud in a direction opposite to that of the drive gear *A* but they must roll around the internal periphery of the gear *B* and carry the disc or plate *D* forward at a slower speed than driving shaft *A* but in the same direction as indicated by arrow *F*. As the drive sprocket is attached to plate *B* it turns at a slower speed than the engine shaft *E*.

Q. Describe action of reverse gearing.

A. In order to obtain a reverse motion it is necessary to provide a brake band for plate *D* and attach the driving sprocket to internal gear *B*. When the plate *D* is kept from rotating the planetary pinions *C* turn around on their studs and rotate the internal gear *B* in a direction opposite to engine rotation, as indicated by the arrow *H*, and at a slower speed than that of the drive gear *A*.

Q. How is direct drive obtained?

A. Direct drive is obtained with any form of planetary gearset by some form of friction clutch which is adapted to lock all parts of the transmission into one rigid unit.

Q. How does the gearset act when on direct drive?

A. When all parts of the planetary gear assembly are locked together the gears are still in mesh but are not turning and the revolving mass acts as a flywheel member.

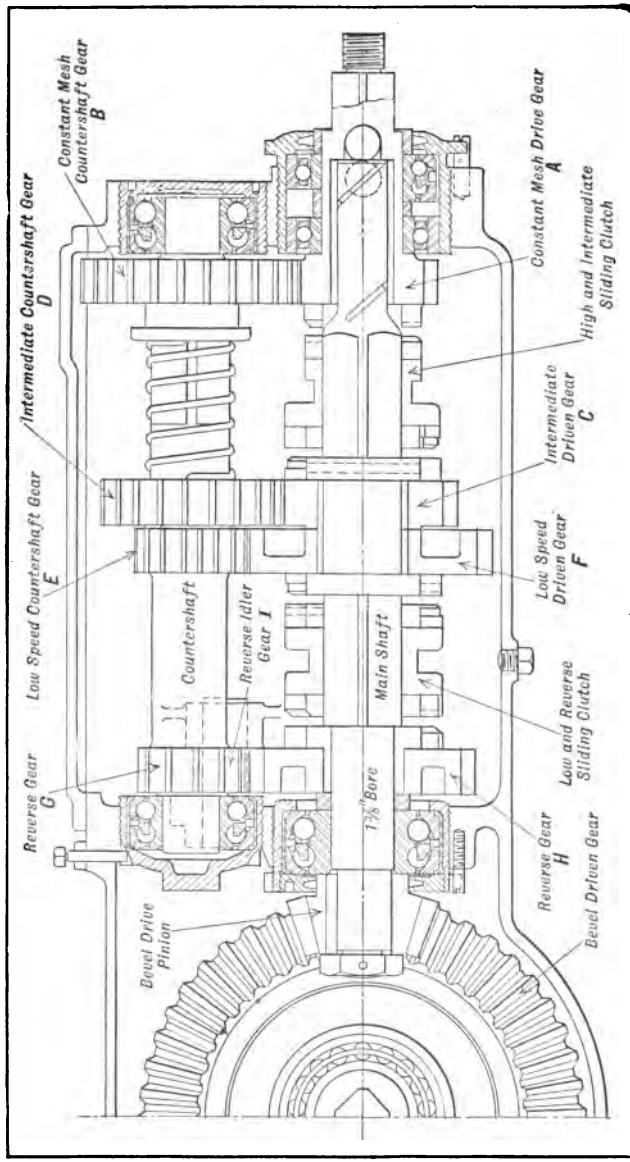


Fig. 160.—Typical Gearset Providing Three Forward Speeds and a Reverse Motion in Which Gears are Always in Mesh and Speed Changes are Effected by Sliding Positive Clutches.

Q. What is the operating principle of the individual clutch gearset with master clutch?

A. In this form of change speed gearing two shafts are provided, one being a main shaft and the other a countershaft. Suitable gears are attached to and turn with the countershaft, these meshing with corresponding members on the main shaft which are normally free to turn unless clutched to the main shaft by some form of positive clutch. A typical individual clutch gearset is shown at Fig. 160 with all parts clearly outlined.

Q. What types of clutches are used in the gear box?

A. The clutches employed to secure the loose gears to the main shaft are of the positive jaw type, one member having projecting teeth designed to engage with the depressions in female member of the clutch. The master clutch is of the friction type and usually is carried with the flywheel. Any form of friction clutch previously described may be used as a master clutch.

Q. Why is the master clutch needed?

A. The positive types of clutches are obviously harsh in action, i. e., they will transmit power as soon as engaged and if these were used alone there would be considerable strain imposed on the mechanism owing to the sudden starting of the car and the clutches themselves would become damaged if they fail to engage promptly. When a master clutch is used in the flywheel, this is released before the positive clutches are shifted and is re-engaged and the power applied to the gearset gradually after the positive clutch has been shifted.

Q. How many speeds can be obtained from individual clutch gearset?

A. Any reasonable number of speeds may be provided in a gearset of the individual clutch type though those commonly constructed provide either three or four forward speeds and a reverse ratio.

Q. Describe construction of typical individual clutch gearset and name important parts.

A. In the individual clutch change speed gearing shown at Fig. 160 the important parts are the casing, the main shaft, which carries

two double end clutches and two loosely revolving members, and the countershaft to which four gears are secured. Both of these shafts are carried on suitable ball-bearings, and the driving end of the main shaft is provided with a bevel drive pinion which engages with a driven gear which forms part of a countershaft carried as part of the gearset. The main shaft is made in two pieces, one end telescoping into the other. The power of the engine is applied to the short portion of the main shaft or sleeve into which the end of the longer shaft telescopes. One of the constant mesh gears is an integral part of the sleeve. This gear is in mesh with a larger member carried by the countershaft.

To obtain a high speed or direct drive, the high and intermediate speed sliding clutch is pushed forward until it engages with the projecting teeth of the constant mesh drive gear. This serves to lock the two portions of the main shaft together and power is transmitted directly from the constant mesh drive gear sleeve which is turned by the engine to the bevel drive pinion. If, however, the high and intermediate sliding clutch is moved toward the back of the gearset in such a way that it locks the intermediate gear *C* to the shaft, then the engine power is transmitted from constant mesh gear *H* to countershaft gear *B* and from intermediate drive gear *D* to the driven gear on the main shaft with which gear *D* meshes. To obtain low or reverse speed the other sliding clutch is moved so that low speed driven gear *F* is locked to the main shaft for the slow speed and reverse gear *H* is locked to the main shaft for reverse motion.

The countershaft turns slower than the drive sleeve of which the constant mesh drive gear *A* forms a part on account of the difference in size between gears *A* and *B*. When the intermediate ratio is desired, practically the only reduction in speed between the engine and the drive pinion is obtained by the difference in size between gears *A* and *B* because gears *C* and *D* are practically the same diameter. On low speed and reverse motion there is a reduction in speed because gear *E* is smaller than gear *F* and gear *G* is smaller than gear *H*. On the direct drive, the speed of the bevel drive pinion and the engine crankshaft is the same. On the intermediate ratio there is one reduction in speed at the constant mesh

gear. On the low and reverse speed, there are two reductions in speed, one at the constant mesh gears and the other between the driving gear on the countershaft and the driven gear on the main shaft. When both clutches are in a neutral position the master clutch may be engaged without driving the transmission main shaft. Before either sliding clutch member is engaged it is necessary to interrupt the engine drive by means of the master clutch.

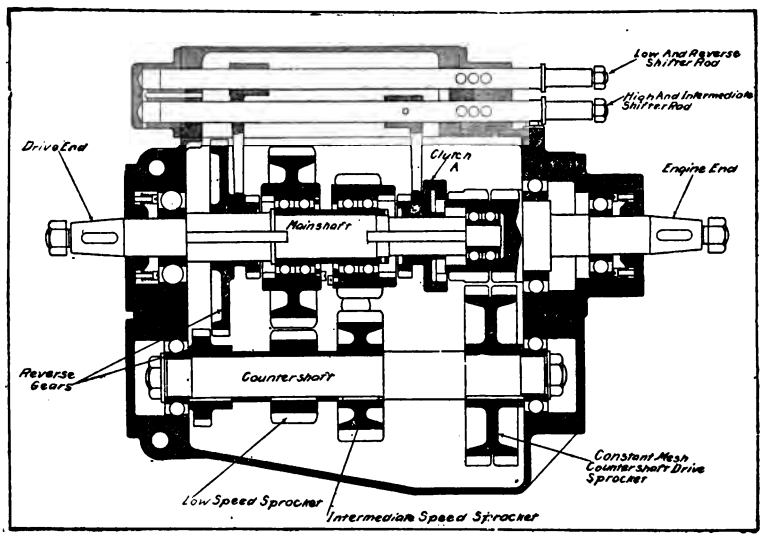


Fig. 161.—Sectional View of Coventry Silent Chain Individual Gear Box With Chains Removed from Gearing to Show Arrangement of Parts.

Q. Are gears the only speed reducing members used in gear-sets of this character?

A. Forms of individual clutch gear boxes have been devised abroad where silent chains are used to connect the main shaft and countershaft instead of having gears in mesh. A gear box of this character with the chains removed is shown at Fig. 161. The various speeds are obtained by sliding clutches, just as in the previously described outfit, the only exception being the method of obtaining the reverse ratio.

Q. How is the reverse drive obtained with silent chain gear box?

A. Instead of using a sliding positive clutch a large gear is slid into mesh with a small gear on the countershaft. Where chains are used both shafts turn in the same direction and the use of a pair of gears reverses the motion of the main shaft relative to that of the countershaft which is turning in the same direction as the constant mesh sprocket driven by the engine.

Q. What are the advantages of the silent chain gear box?

A. It is contended that in heavy vehicle service such as motor truck work or in omnibuses that it is necessary to use the lower gear ratios a large part of the time. The ordinary forms of gear boxes are noisy when in use and become more noisy as the parts wear. If silent chains are used the gearing is quieter and more enduring than the conventional form of spur gear construction.

LESSON EIGHTEEN

ACTION OF SLIDING GEAR TRANSMISSION

Q. What are the essential parts of a sliding gearset?

A. The sectional view of gearset outlined at Fig. 162 clearly shows the principal parts of a sliding gearset and their relation to each other. Two shafts are provided, one of which is divided in two parts and is called the main shaft or transmission shaft, while the other shaft is a solid member and is termed the "countershaft." The gears on the countershaft are keyed to it while those on the main shaft are adapted to be moved back and forth by shifting forks carried on gear shifting shafts. The shafts are supported on suitable bearings preferably of the anti-fr ction type and the entire assembly is housed in an oil tight aluminum casing.

Q. How does the sliding gearset differ from the individual clutch type?

A. The sliding gearset is so called because speed changes are effected by sliding one gear into engagement with a corresponding member on the countershaft. In the individual clutch forms, all gears are always in mesh, whereas in the sliding gear type only the gears that are used in transmitting power are engaged. In both forms of transmission there is one pair of gears that are constantly meshed and the main shaft construction is just the same in either the sliding gear or individual clutch forms. One end of the main shaft proper telescopes into a member which carries the constant mesh gear and to which the clutch shaft is attached. Instead of shifting the clutches as in the individual clutch form the gears themselves are moved along the keys on the main shaft.

Q. Name the two main types of sliding gearsets.

A. Two forms of sliding gear arrangements have received general application namely the progressive system in which one shift-

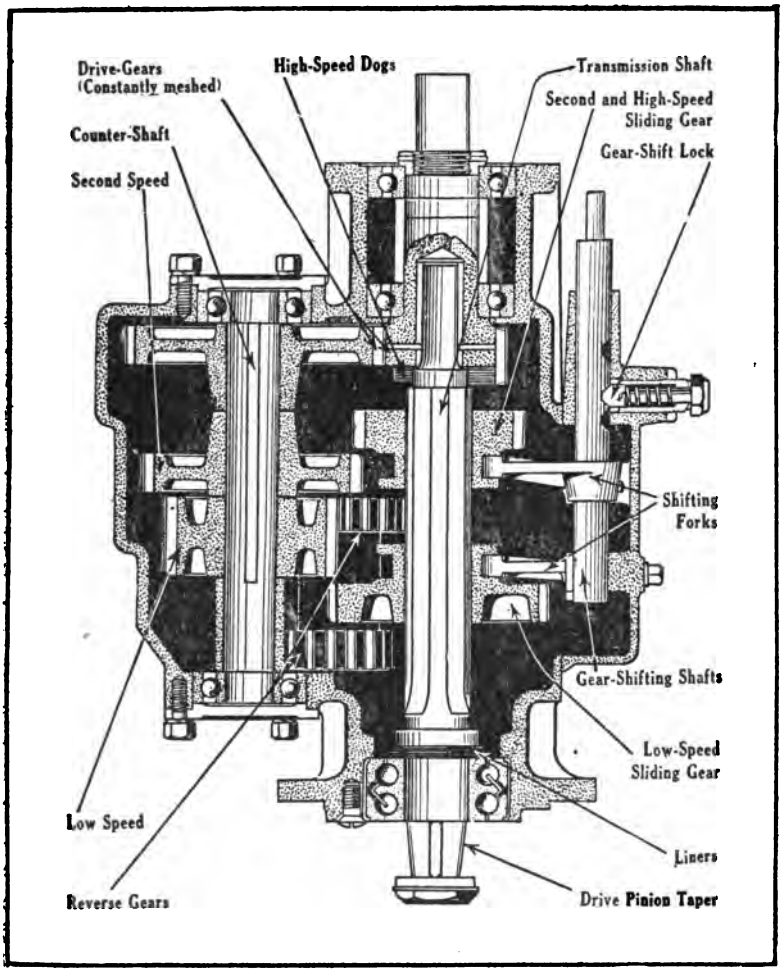


Fig. 162.—Three-Speed Sliding Gear Set of the Selective Type Used in Overland Cars Showing Principal Parts.

ing member serves for all speeds and the selective system where two or more sliding gear members are used.

Q. Describe construction of simple three speed progressive sliding change speed gearing.

A. A typical progressive sliding gear assembly is outlined at

Fig. 163 and the arrangement of parts is clearly shown. In general construction it is the same as all sliding gear transmissions, having a main shaft which telescopes into the driving member to which the clutch cone is attached. One common shifting member, which is composed of the gears *K* and *I* and the positive jaw clutch *J*, is adapted to slide along the main shaft from one end to the other. This shifting member is moved by a gear shift lever which works on the segment providing five positions for the shift lever. Each of these positions is indicated by a notch cut into the guide segment and a simple form of locking member is employed to hold the lever in position in any one of the desired speed ratios. A transmission of this form is called "progressive" because the various speeds must be obtained in a constant unchanged ratio. For instance, if one is in the neutral position indicated and it is desired to go into the high speed, it is necessary to first pass through the intermediate ratio, before one can engage the high speed clutch. If one is in the reverse position and wishes to go to the high speed, the hand lever must be shifted through the slow speed and intermediate gears progressively before the direct drive is obtained.

Q. Outline method of obtaining low speed.

A. The low speed ratio is obtained by moving the hand lever back into a notch on the segment, which moves the bell crank and pushes the sliding member along the squared main shaft until gear *K* of the sliding member engages gear *F* on the countershaft. As previously stated the member of which gear *A* forms a part is normally independent of the squared main shaft and drives the countershaft through the medium of the gear *B*. There is a difference in size between the constant mesh gears and the countershaft turns slower than the gear member *A*. The power applied to the countershaft is transmitted back to the squared portion of the main shaft to which the universal driving joint is attached, by the small gear *F* which is one-half the diameter of gear *K* so that there is a reduction in speed of about four to one, meaning that the clutch cone will revolve four times to one revolution of the universal joint.

Q. Describe action when on intermediate speed.

A. To obtain an intermediate ratio the gear shift lever is moved

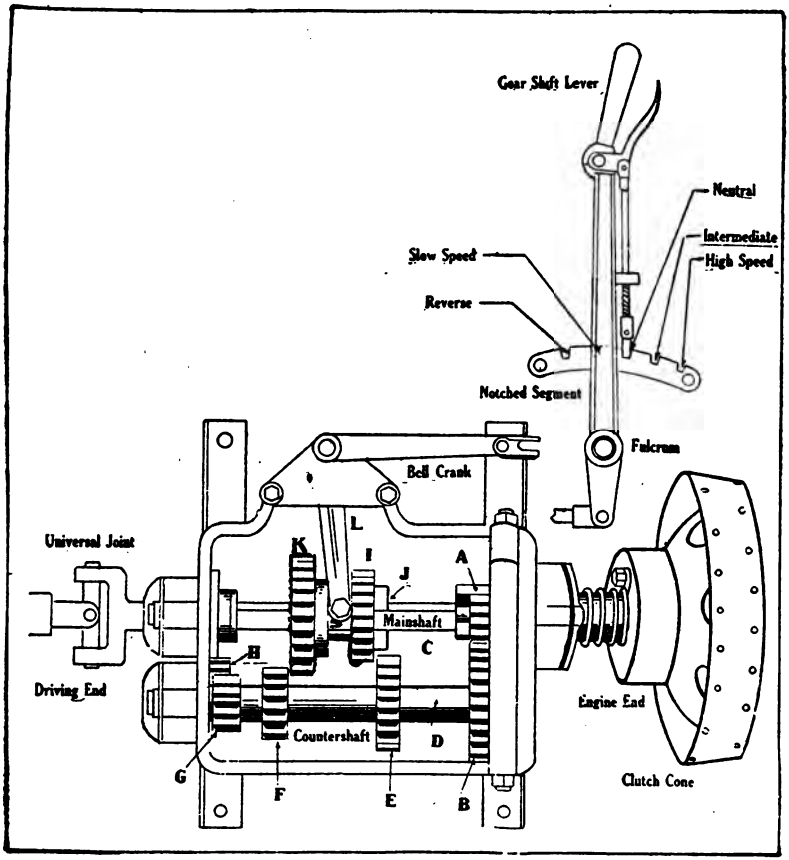


Fig. 163.—Outlining Construction and Method of Operating Three-Speed Progressive Gearset.

from the neutral notch of the segment indicated at Fig. 163 to the intermediate notch on the segment. This pushes the sliding member forward so that the gear *I* on the main shaft engages the gear *E* which is the same size, on the countershaft. As before, the drive is through gear *A* to gear *B*, which gives the countershaft half the speed of gear *A* and then from gear *E* to gear *I* on the main shaft wh ch turns that member at the same speed as the countershaft so that a gear ratio of two to one is obtained.

Q. Describe action of gearset when on high speed.

A. The highest speed is usually a direct drive obtained by locking the two members comprising the main shaft assembly together by a positive jaw clutch *J* carried on the face of the gear *I*. To engage this clutch it is necessary to push the hand lever into the extreme forward notch on the segment which moves the bell crank so that teeth *J* fit into the corresponding depressions on the face of gear *A*. As the main shaft is practically one-piece the drive is direct from the clutch cone to the universal joint.

Q. Outline method of obtaining reverse motion.

A. In order to turn the universal joint at the driving end in a reverse direction to that of the clutch cone it is necessary to push gear *K* to the extreme back end of the gearset where it meshes with an intermediate pinion *H* carried by a stud on the gear case instead of directly with member *G* on the countershaft. The motion of the countershaft *D* is always reversed to that of the main driving member *A* though the motion is again reversed on any of the forward speed ratios so that the squared portion of the main shaft turns in the same direction as the gear *A* though at a slower speed. By the interposition of the intermediate pinion *H* which meshes with the countershaft gear *G* the motion of the main shaft is made to correspond to that of the countershaft if the gear *K* is pushed into engagement with the intermediate pinion *H* and thus the universal joint is turned in a direction opposite to that of the engine

Q. What is a selective gearset?

A. The selective form of gearset, as outlined at Fig. 162 and 164, is practically the same in general principles of operation as the progressive system except that two or more shifting members, each operated by an independent rod, are employed instead of the one shifting member of the progressive gearset. One gear shift lever is employed for both shifting members and this works in a gate form of segment so the lever may be moved in or out to engage either shifting member as desired. As the shifting member may be picked out by merely pushing the gear shift lever into the proper slot in the gate plate this system is called the selective system.

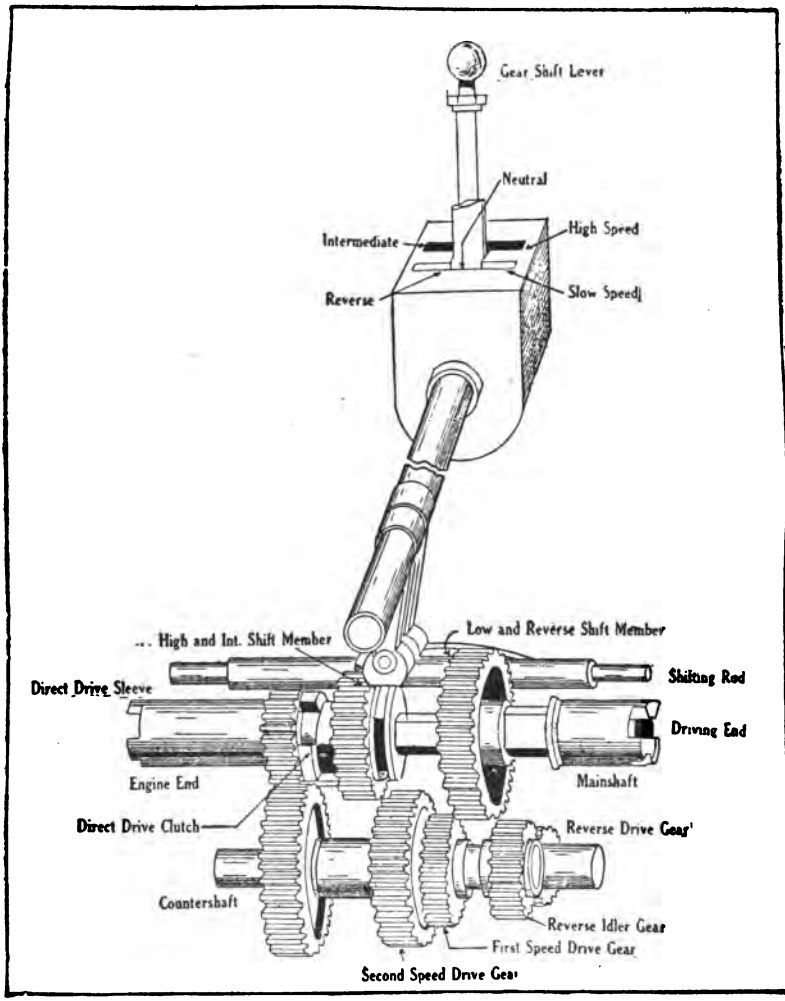


Fig. 164.—Defining Arrangement of Parts and Method of Operating Sliding Members of Three-Speed Selective Gearset.

Q. What are the main advantages of a selective gearset?

A. An important advantage of the selective system of gear shifting is that a more compact construction is possible than in the progressive system and gears can be engaged more easily. When

the gearshift lever is in neutral position, one can go directly into any desired speed ratio without passing through any of the others if desired. This enables the driver to select the speed he desires at once. For example, if the gearshift lever was in a position at the back end of the inside slot, as shown at Fig. 164, the low and reverse shift member would be engaged with the reverse idler gear. If it is desired to pass directly into the high speed position this

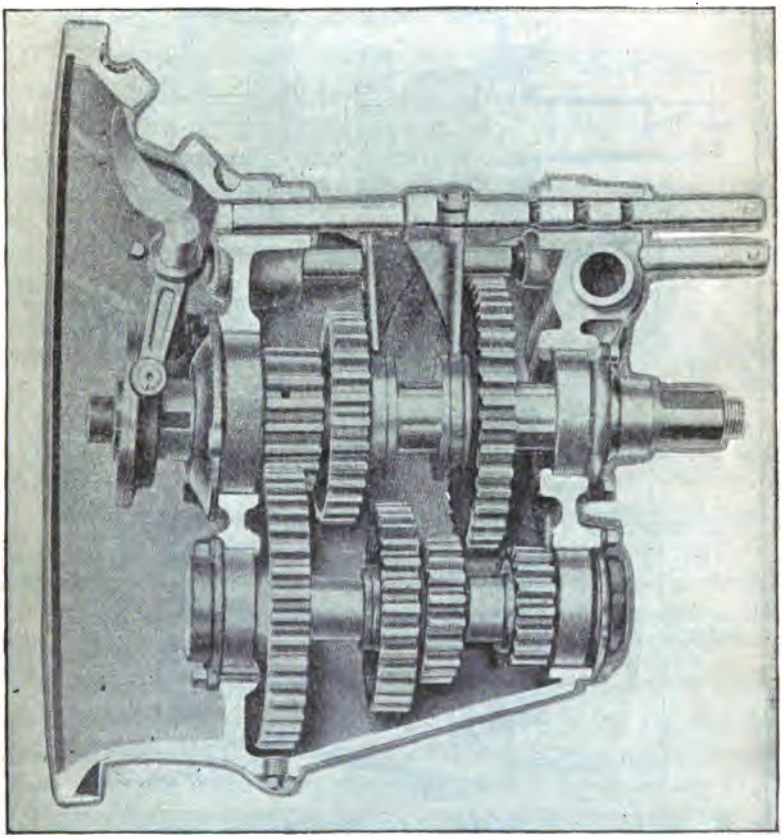


Fig. 165.—Part Sectional View of Three-Speed Selective Gearset Adapted for Use in Combination With Motor to Form Unit Power Plant.

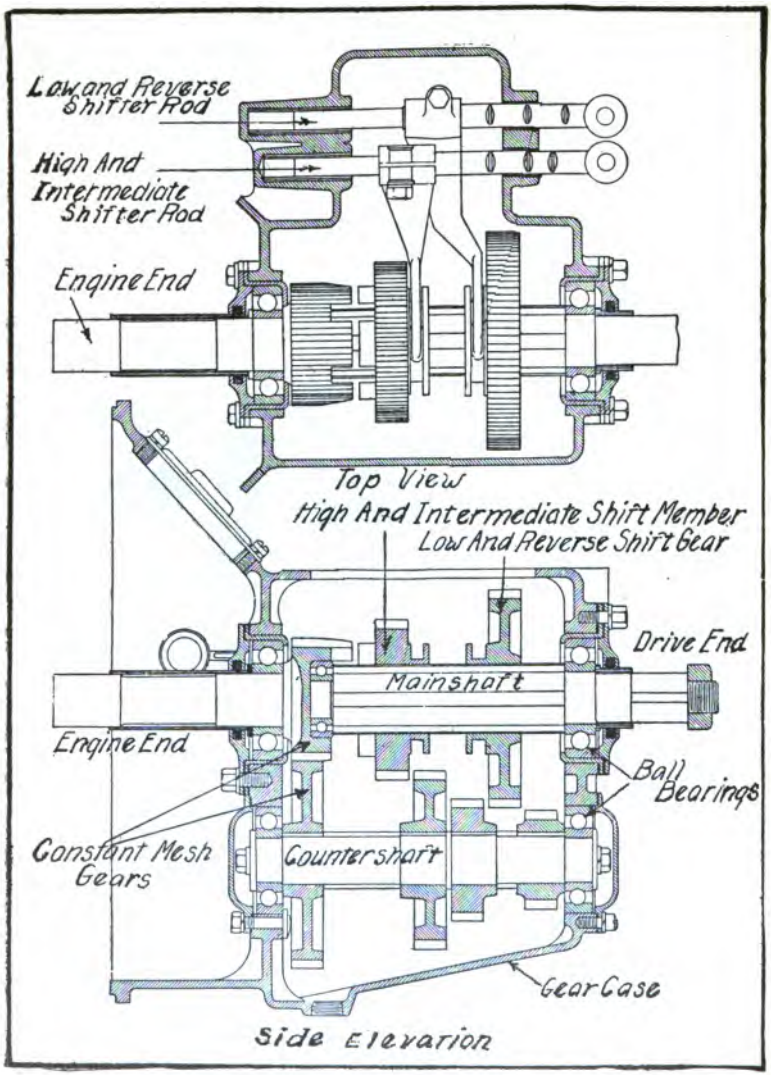


Fig. 166.—Top and Side Views Showing Construction of Three-Speed Gearset for Unit Power Plant.

could be accomplished by a simple movement of the gear shift lever to the front end of the outside slot which would engage the direct drive clutch. With a progressive gearset it would be necessary to pass through low and intermediate ratios before the high speed clutch could be engaged. This would not only require an appreciable interval of time but would also produce more wear on the gears comprising the shifting member which would be often moved through one or more speed ratios when this would not be necessary with the ordinary selective system.

Q. How many speed changes are provided in the usual selective gearset?

A. Selective change speed gearing used on light and medium weight cars, such as depicted in halftone at Fig. 165 and in engineering drawing at Fig. 166, provide for three forward speeds and a reverse motion. As a rule the highest speed is obtained by locking both members comprising the main shaft assembly together. On heavier, more powerful cars, a gearset such as shown at Fig. 167 and providing four forward speeds and a reverse motion is often supplied. Four speed gearsets may be of two patterns, the form outlined having the highest or fourth speed on the direct drive while other forms have the direct drive on the third speed.

Q. In a four speed gearset with direct drive on the third speed how is the highest or fourth speed obtained?

A. Where the direct drive lock is utilized for the third speed of a four speed gearset the highest ratio is usually through gearing arranged in such a way that when the fourth speed is engaged the driving end of the gearset will turn at a higher speed than the engine end.

Q. What are the advantages of the geared-up fourth speed?

A. In a four speed gear box having direct drive on the third ratio it is intended that all normal driving will be on the third speed which provides maximum efficiency. When exceptionally favorable conditions are present and it is desired to drive the car at a high rate of speed, the geared-up fourth speed may be brought into action for the short time it is possible to maintain the high speed. The direct drive position permits of utilizing a lower ratio of drive

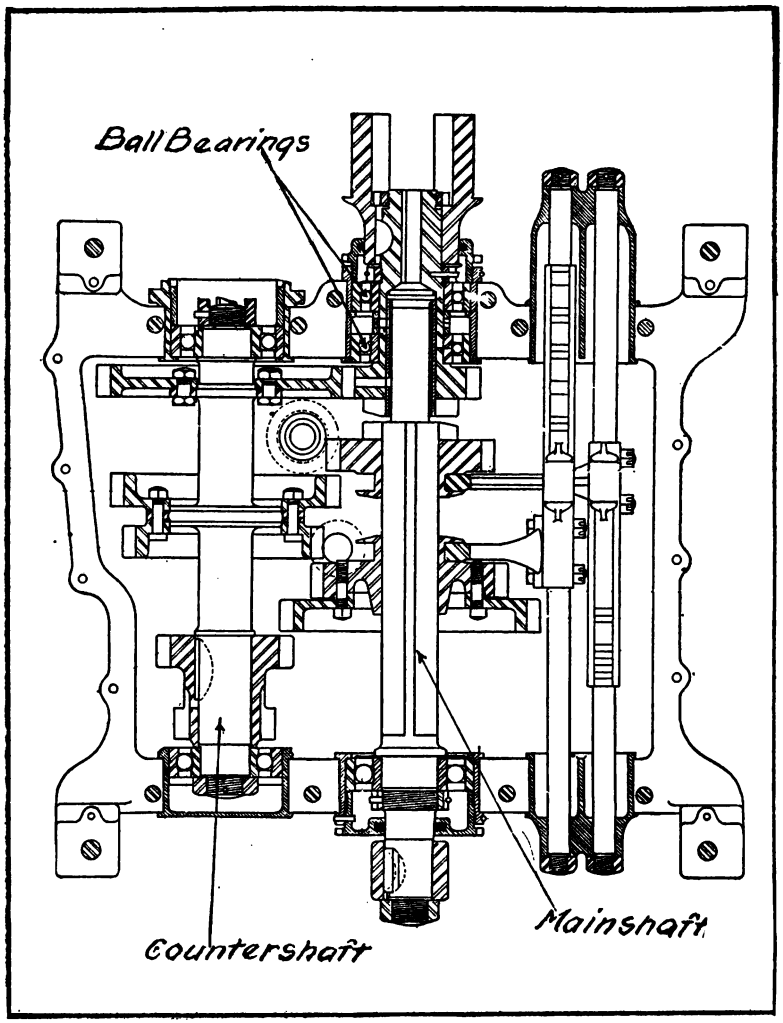


Fig. 167.—Selective Gearset of Locomobile Design Provides Four Forward Speeds With Direct Drive on Fourth Speed.

at the rear wheels than would be possible if the direct drive lock was depended on for the highest speed ratio.

With a four speed gear box with direct drive on the third, one can

do more driving under the conditions of maximum efficiency than would be permissible with the higher gear ratio provided when direct drive is on the fourth speed. In one instance, efficiency is sacrificed to some extent on the highest ratio which is used but 25% of the time to obtain the maximum efficiency on the speed ratio that is used over 50% of the time. With the direct drive fourth speed the third speed gears are often used and considerable power is lost through the gearing which would be conserved if the third speed was a direct drive instead of the fourth.

Q. Where is the gearset usually placed?

A. It is common practice to p ace the gearset as an independ-

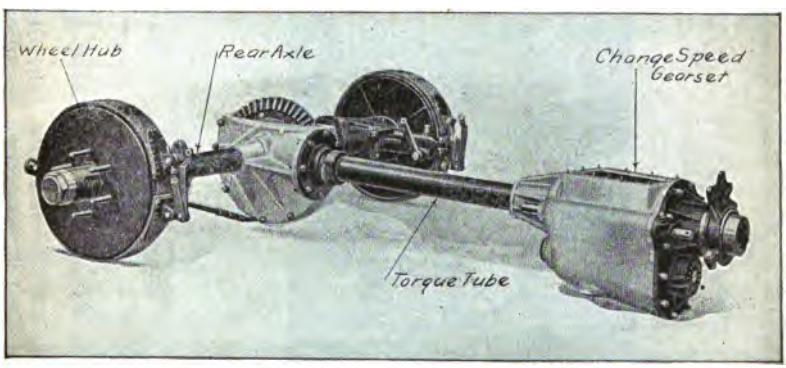


Fig. 168.—Gearset Located at Front End of Torque Tube and Forming a Unit With Rear Axle Structure.

ent unit immediately back of the clutch which usually forms part of the power plant. This brings the change speed gearing almost directly under the floorboards at the front end of the car.

Q. Name other methods of gearset placing?

A. The gearset may be placed as a unit with the power plant; at the front end of the torque tube of the rear axle, as shown at Fig. 168, as part of a jack shaft assembly when used in motor trucks, as at Fig. 169, or attached directly to the rear axle, as shown at Fig. 170.

Q. What are the advantages of unit gearset and power plant or axle assembly?

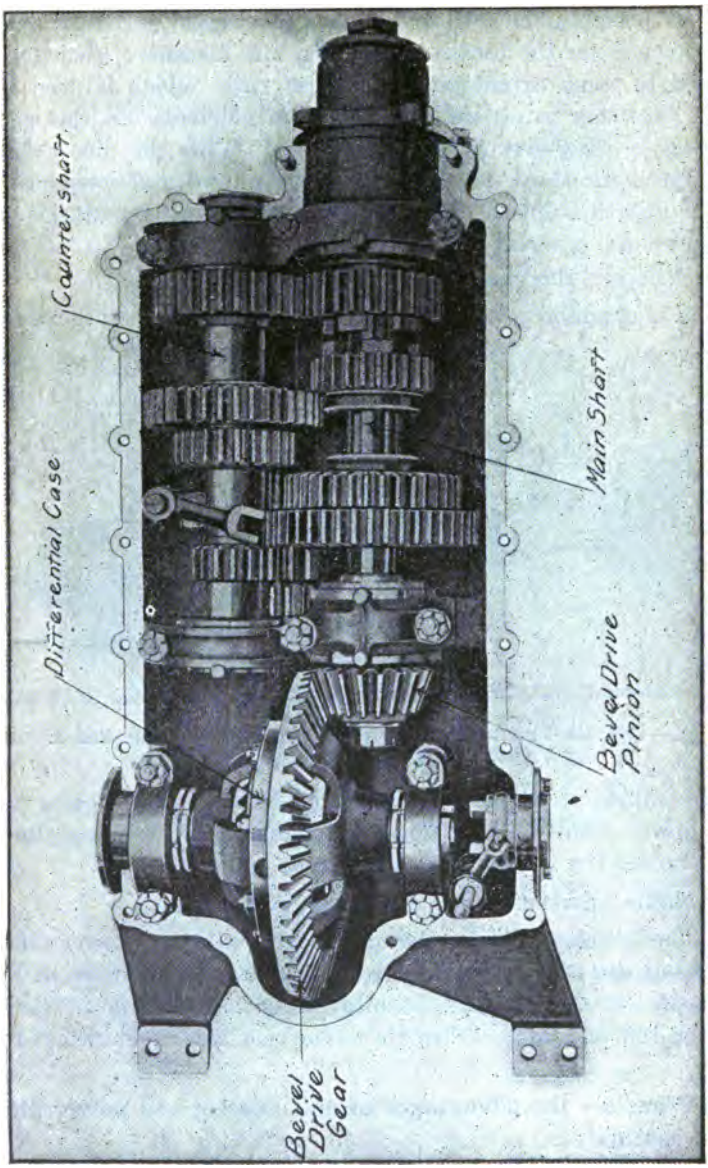


Fig. 169.—Four-Speed Motor Truck Gearset With Drive Pinion, Ring Gear and Differential Assembly Incorporated in Same Case and Used in Connection With Counter Shaft Drive.

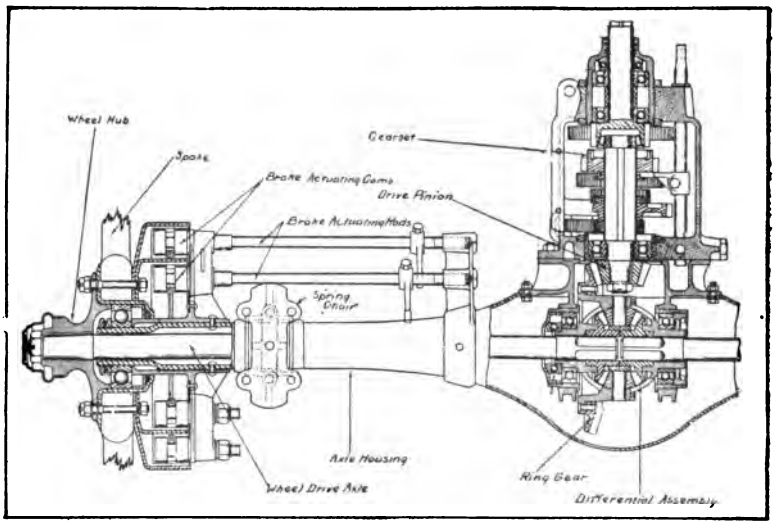


Fig. 170.—Gearset Located at McCue Rear Axle.

A. The important advantage of combining the gearset with either the power plant or driving member or the rear axle driven member is that the parts are kept in absolute alinement because there is no possibility of the gearset getting out of line with the crankshaft if it is housed in a part of the motor case or to lose its alinement relative to the driving gearing if it is part of the rear axle or countershaft assembly.

LESSON NINETEEN

METHODS OF DRIVE TO REAR WHEELS

Q. Describe common methods of power transmission in automobiles.

A. The power of the engine is usually transmitted from the speed changing mechanism to the rear wheels by some method of positive drive mechanism which may be bevel, spur, or worm gearing, or sprocket and chains.

Q. What is the influence of power plant location on method of drive?

A. The arrangement of the power plant relative to the rear axle has material influence on the method of drive employed. If the engine is a simple form with the crankshaft at right angles to the frame side it is customary to drive directly from a simple planetary gearing on the crankshaft to a live axle by a chain. If the engine is located in such a way that the crankshaft is parallel to the frame members, then a shaft is employed to transmit the power from the gearset directly to gearing in the rear axle or from sprockets on a countershaft to similar members on the rear wheels.

Q. What is the influence of gear ratio on final drive?

A. When low gear ratios are desired, as on heavy commercial cars, it is necessary to use either a double reduction drive system or worm gearing, if a single reduction is employed.

Q. What determines the speed reduction needed between driving and driven members?

A. The ratio of rear wheel speed relative to that of the crankshaft of the power plant depends upon the amount of power available, the maximum speed it is desired to attain, and the weight of the vehicle. On high powered pleasure cars, where high speeds

are required and where powerful engines are provided, it is possible to gear the rear axle in such a way that the engine will make two and one half to three turns while the rear wheels make one revolution. On low powered touring cars the reduction is usually four to one, while on heavy commercial vehicles the reduction will range from eight to twelve to one and even greater than this if a small engine is required to move a heavy load. Obviously, the lower the reduction, the less speed obtained for a given number of engine revolutions.

Q. Describe cheapest method of direct drive.

A. The cheap-

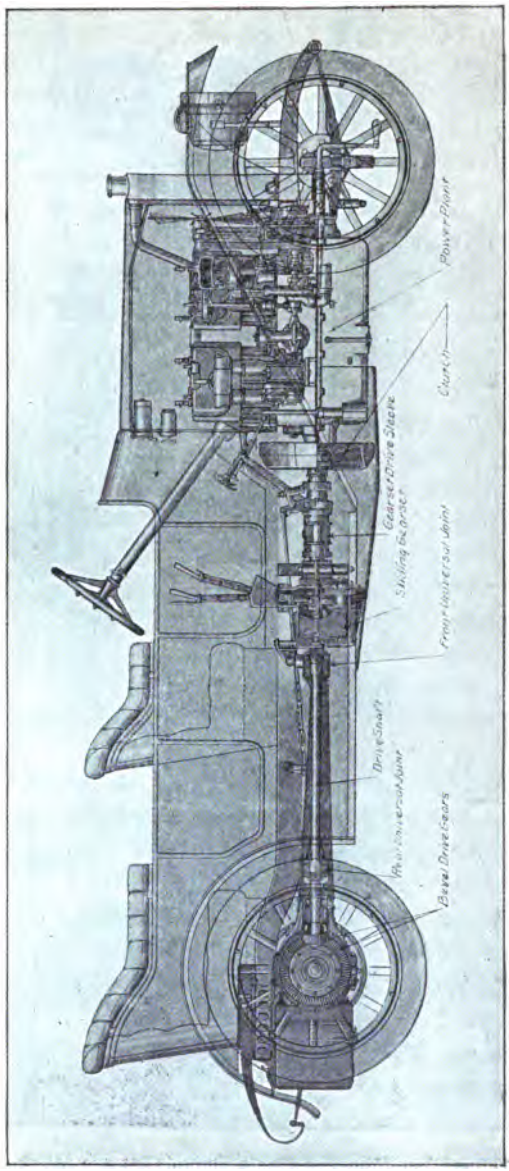


Fig. 171.—Side View of Typical Shaft-Driven Chassis Showing Driving Shaft With Two Universal Joints and Arrangement of Parts of Power Transmission System.

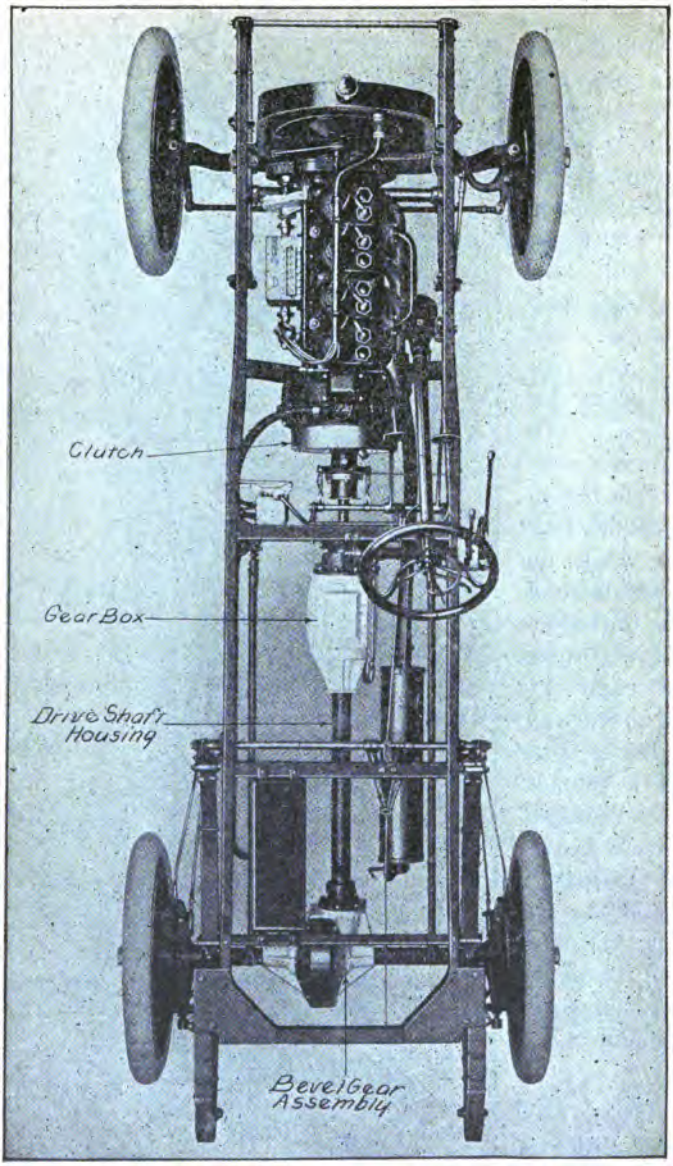


Fig. 172.—Plan View of Shaft-Drive Chassis With Enclosed Drive Shaft and Gearset Mounted at Front End of Torque Tube.

est method of direct drive is by attaching the engine direct y to the rear axle and driving from the crankshaft to the differential case by a pair of spur gears. This method is used only on steam carriages at the present time and on some forms of electric automobiles, though in the latter application compound gearing is generally used to obtain the desired low ratio. Another simple driving means which is used at the present time only on two or three makes of cars employing friction transmissions is to join the transmission shaft directly to the rear axle by some form of driving chain.

Q. Describe method of direct drive ordinarily used.

A. The method of direct drive ordinarily used is shown at Figs. 171 and 172. In the former the drive shaft which transmits power from the sliding gearset to the bevel driving gears at the rear axle is provided with two universal joints, one at each end and is exposed. The driving and braking strains on the axle are resisted by a pressed steel member extending from the rear axle to the rear frame across member that supports the gearset. At Fig. 172 the same method of drive is employed except that but one universal joint is used and the driving shaft is enclosed in a tubular housing that also serves as a torque member.

Q. What is an efficient method of direct drive when speed reduction ratio is low?

A. A worm drive assembly, such as outlined at Fig. 173, provides a very satisfactory method of drive where a low reduction ratio is desired without using compound gearing or a double reduction. The worm has a tooth angle of about 45 degrees and drives the worm wheel, which is provided with angularly disposed teeth placed around its circumference

Q. Name parts of compound drive or double reduction system generally used.

A. Where a lower gear reduction is desired than is possible to obtain by the use of a direct drive connection the compound drive as shown at Fig. 174 is utilized. In this the power is transmitted from the engine to a countershaft placed across the frame; the drive from engine to the countershaft is by means o bevel gears

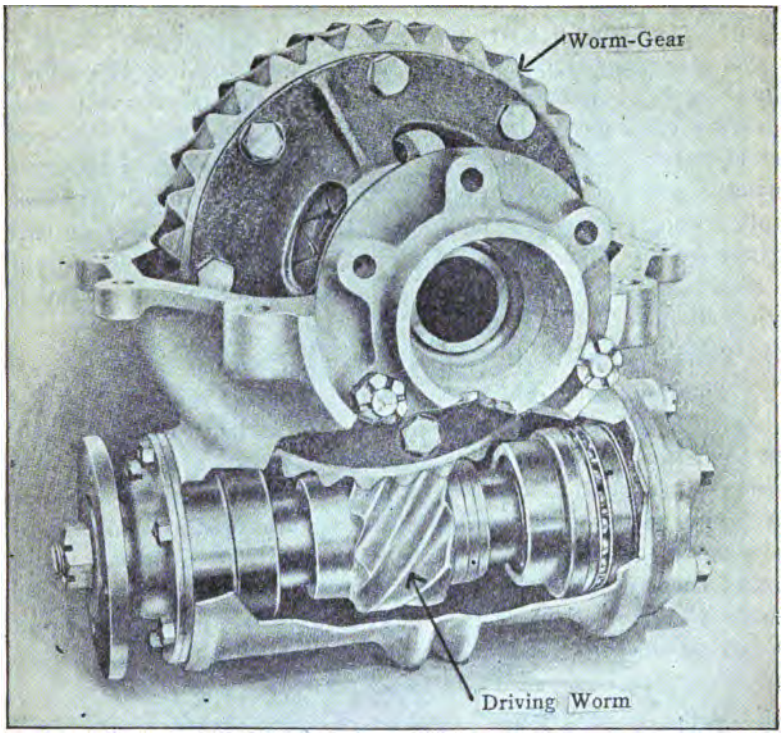


Fig. 173.—Part Sectional View of Worm Gear Drive Assembly With Worm Placed Beneath the Axle.

just as in the usual form of live axle. In fact, the average countershaft assembly is practically a live rear axle with sprockets placed at the axle ends which in turn transmit the power to rear wheels revolving independently of each other on a fixed non-rotating axle which supports the car weight. One reduction ratio is obtained between the bevel gears of the countershaft and the speed is still further reduced by making the drive sprockets on the rear wheels larger in diameter than those on the countershaft. The racing chassis at Fig. 175 shows the method of using side chain drive with enclosed chains that is used on heavy touring cars while the illustration Fig. 176 shows the usual exposed chain employed in motor trucks.

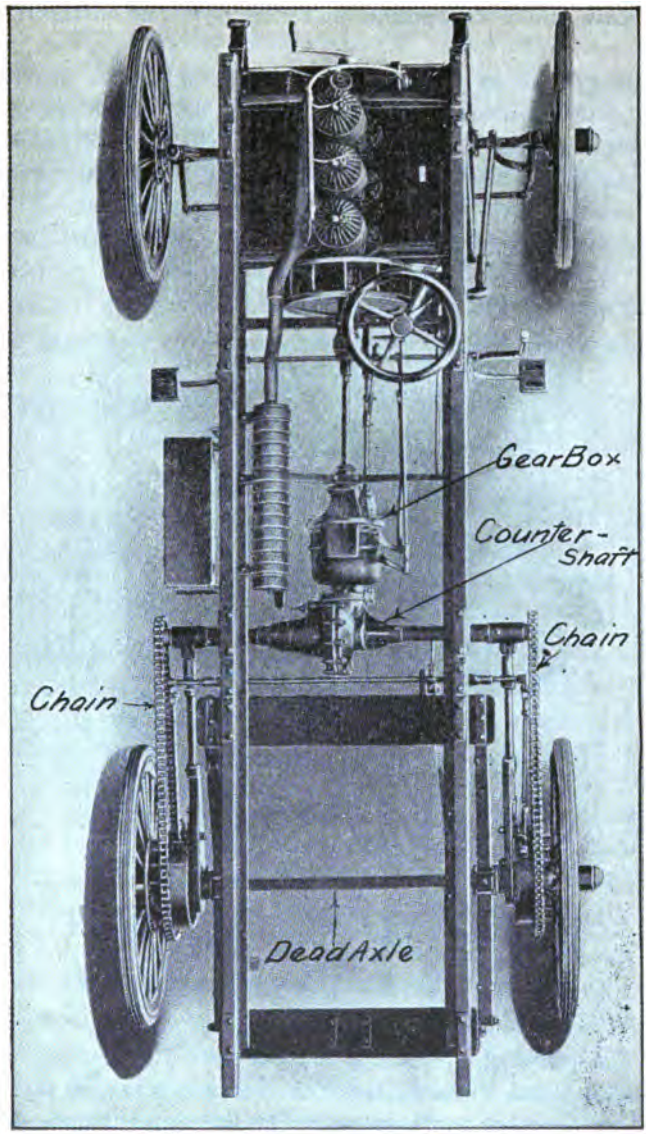


Fig. 174.—Plan View of Light Truck Chassis Having a Double Reduction With Final Drive by Chains and Change Speed Gearing Located on Counter Shaft.

Q. How can a compound drive be obtained without use of chains?

A. Some rear axle constructions are designed to use two sets of gears and thus a compound drive is possible without using chains. For example the drive from the gearset will be to a bevel pinion which engages a bevel gear mounted on a short countershaft inside of the rear axle housing, and this countershaft carries a small spur pinion which engages with a large spur gear on the differential casing. Other forms have bevel gear drive to the center of the axle and have a small spur pinion at the end of each live axle shaft which engages a large internal spur gear that forms part of the brake drum. In this method of construction the rear axle is virtually two members, the greater part of the car weight being carried on

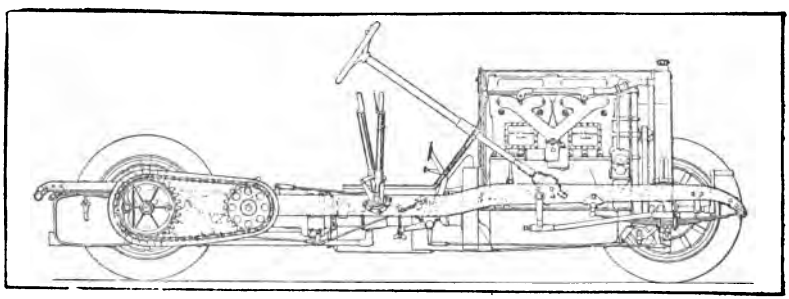


Fig. 175.—Side View of Touring Car Chassis Using Chain Drive.

a non-rotating dead axle on which the wheels revolve while the power transmission is through an auxiliary live axle assembly attached to the fixed axle and used only to transmit power.

Q. What are the common forms of driving chains?

A. The chains ordinarily used for power transmission purposes are the block, roller and silent chains, as outlined at Fig. 177.

Q. What is chain pitch?

A. The pitch of a chain is a term used in speaking of chain sizes and it is the distance between the center of one tooth space to that of the other tooth space in the link immediately adjacent.

Q. What is the difference between a block and roller chain?

A. As will be seen by reference to Fig. 177-A the block chain is composed of the fewest parts, being made up of approximately B shaped blocks joined together by means of side plates or links of the same pattern, the links being held together by through rivets which form a bearing for the chain blocks. In the roller chain as outlined at *B*, the blocks are replaced by compound members formed of two side plates held together by tubular bushings on which hardened steel rollers revolve, in addition to the usual link and rivet. The advantage of the roller chain is that it rolls over the

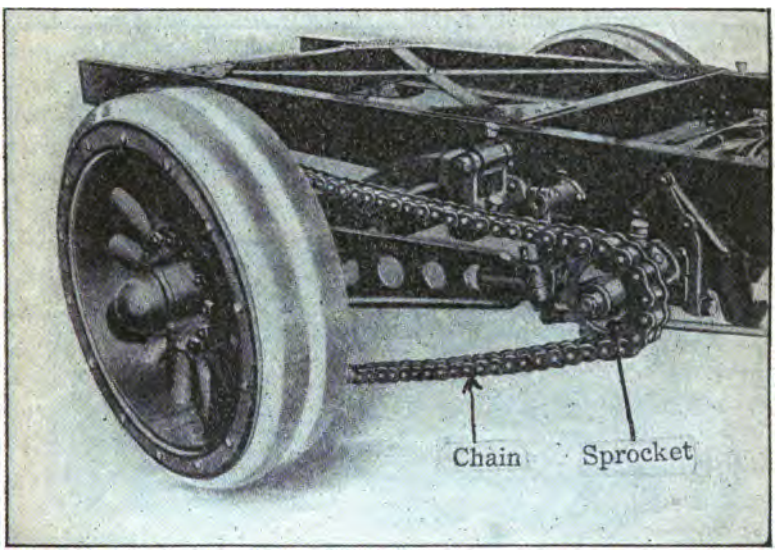


Fig. 176.—Rear End of Motor Truck Frame Showing Method of Driving Rear Wheel From Jack Shaft by Means of Roller Chains.

sprocket with less friction and wear than a block chain and it is used to the entire exclusion of the simpler form in automobile power transmission systems.

Q. What is a silent chain and how is silence obtained?

A. The silent chain is the form in which toothed links are employed which engage with suitable depressions in the sprocket which is directly opposite in action to that of the block and roller

chains in which the sprocket teeth fit openings in the chain. In the silent chain outlined at Fig. 177-C the individual link members are practically the same and the chain is made up of a large number of these link plates held together by side plates of the usual pattern in order to obtain greater strength. A silent chain is quieter in action than either a block or roller chain, because as it runs over the sprocket the tendency of the downwardly projecting teeth is to entirely fill the spaces made to receive them in the sprockets by spreading apart so there is no lost motion between the chain and sprockets, thus noise is reduced appreciably.

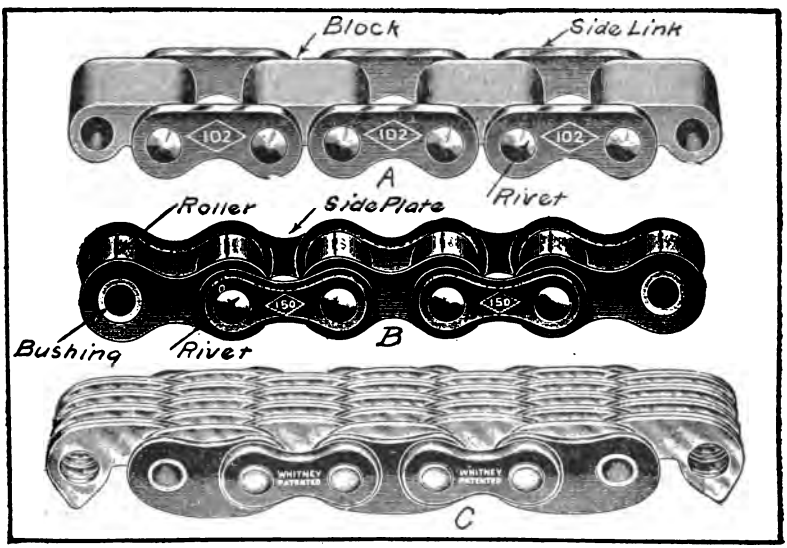


Fig. 177.—Forms of Driving Chains That Have Received General Application. A—Block Chain. B—Roller Chain. C—Silent Chain.

Q. Why is enclosed chain drive better than open drive?

A. In order to obtain satisfactory service from driving chains it is necessary that these be kept well lubricated and free from dirt or grit that will produce wear at the bearing surfaces. If a driving chain is run without a case the particles of dirt and grit that adhere to the links not only absorb the lubricant but interpose an item of friction between the parts of the chain as well as

between the chain and the sprockets that means considerable power loss. While it is possible to run block and roller chains without casing it is absolutely necessary to protect the silent chain and keep it thoroughly oiled or it will soon depreciate. The life of an enclosed chain is three or four times greater than that of an unprotected chain doing the same work and it will be quieter in operation on account of the coating of lubricant.

Q. What are the advantages of gear drive?

A. The advantage that enclosed bevel or worm gear drive offers is that these parts are maintained at a point of high efficiency because they are kept from the dirt and are always properly lubricated. The efficiency of gearing when properly meshed and kept clean and well oiled is very high and the usual arrangement of the driving gears of the rear axle produces a compact and enduring mechanism.

Q. What are universal joints and why are they needed?

A. Universal joints are flexible driving members which are not so flexible as to fail to provide a positive drive between shafts that may not always remain in proper alinement. Universal joints are needed on all driving shafts transmitting power from one member carried on the frame to the gearing at the rear axle because the movement of the rear axle is independent of that of the frame which is supported by resilient, yielding springs. Without universal joints the driving shaft would be subjected to much strain as the parts of the chassis mounted on the springs would move at a different ratio than those carried directly by the tires. Most open propeller shafts use two universal joints, while enclosed shafts need but one, at the front end.

Q. Compare the various methods of final drive with relation to their efficiency.

A. The most efficient means of final drive is by worm gearing which is said to have an efficiency ranging from 90 to 95%. Single chain drive follows with an efficiency of about 90% when new and properly oiled. Then bevel gearing follows with an efficiency of about 85% while the various forms of compound gears are the least efficient, the power loss in transmission ranging from 20%

in a combined spur and beveled gear reduction to 30 or 35% with beveled gear and side chain reduction.

Q. What is the skew bevel gear drive and what are its advantages?

A. The skew bevel or worm bevel, as it is sometimes called, differs from the regular form of bevel gear in that the teeth on pinion and ring gear are cut on an angle, as in worm gearing. The construction of typical skew bevel driving gears detached from the differential casing is shown in illustration Fig. 177-a, the view at the left being of the gears detached from the differential assembly while that at the right shows the application to the rear axle used on Packard motor cars. It is claimed that the skew bevel produces increased quietness of drive as backlash or looseness between the teeth, which is a common cause of noisy action of conventional bevel gearing, is entirely eliminated by the angular teeth. It is also claimed that whereas ordinary bevel gearing has a straight line contact, the worm bevel with its curved teeth has one set of teeth constantly meshing while the next set is becoming disengaged. This affords a continuous contact, in some degree the same as accomplished with worm gearing.

Q. Are gasoline automobiles always driven by the rear wheels?

A. Gasoline automobiles have been designed where the drive is through all four wheels which combine directive and tractive functions. A side elevation of the new Rambler four wheel drive motor truck with important parts depicted is clearly shown at Fig. 177-b. In this the power is obtained by the regular Rambler power plant driving through a dry disc clutch to a change speed gear of special construction mounted on the chassis frame about midway between the front and rear axles. One drive shaft extends from the front end to the front axle while a similar member transmits power to the rear axle which is a duplicate of that used at the front of the car.

The special form of gear box necessary is outlined at Fig. 177-c. In this the drive is through gearing at all speeds, there being no direct drive clutch as is true of conventional gear sets. The transmission provides four speeds forward and a reverse and in ad-

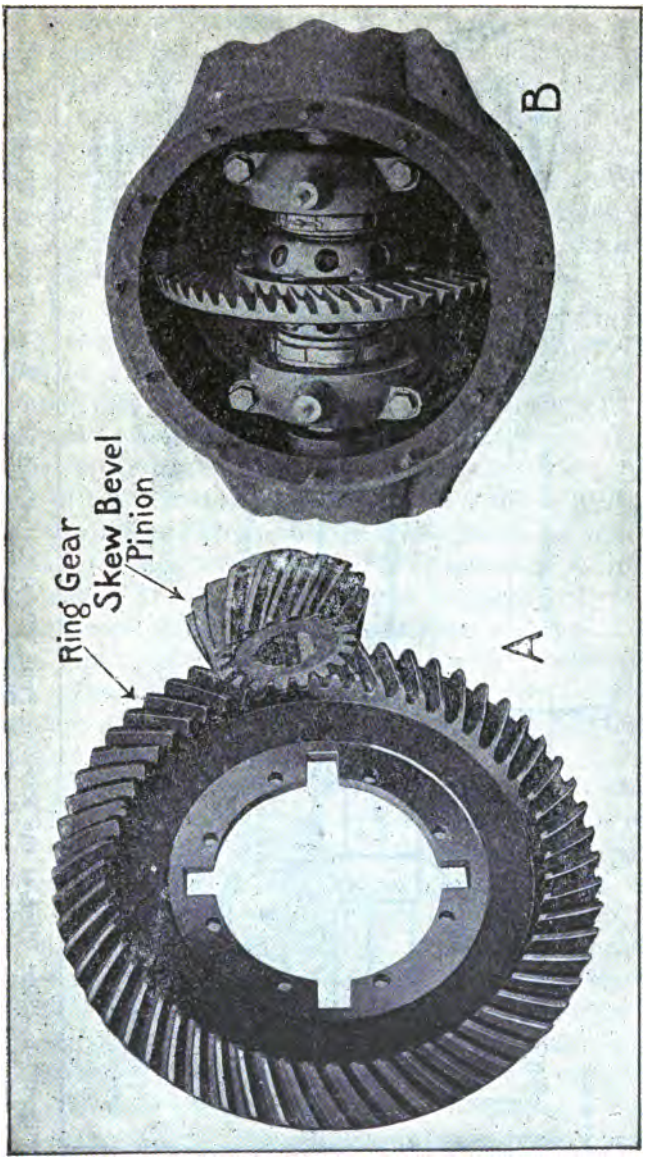


Fig. 177-a.—The Packard Skew Bevel Driving Gear Construction, in Which Angular Teeth are Used to Provide Quiet Operation.

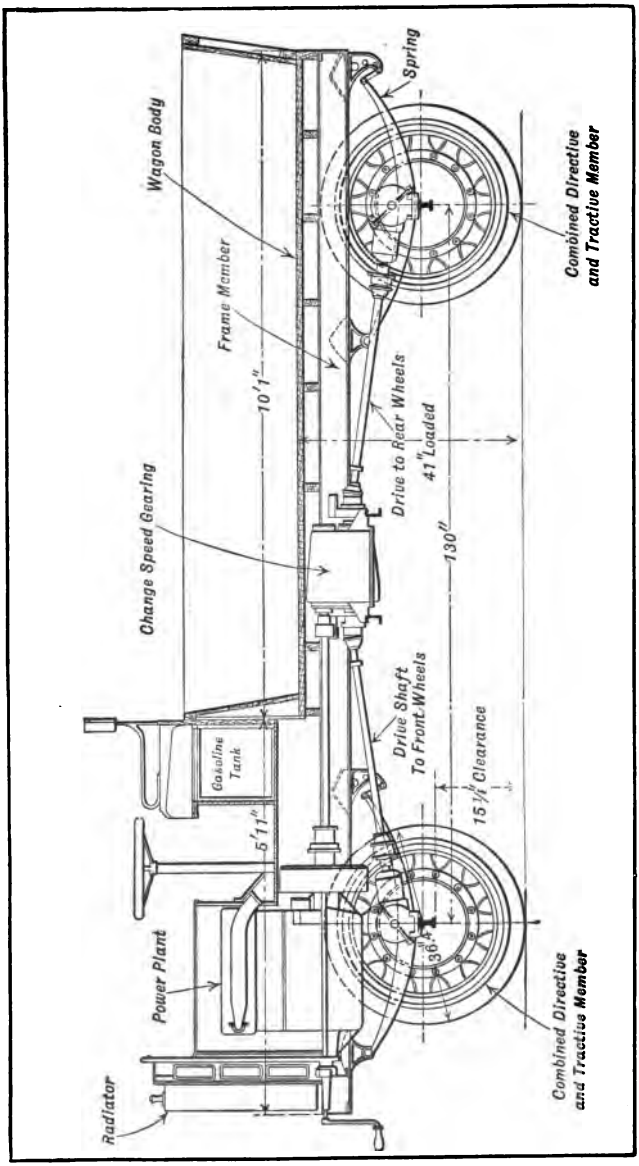


Fig. 177-b.—Side View of the Rambler Four Wheel Drive and Steer Motor Truck, in Which All Wheels Combine Directive and Tractive Functions.

dition to the usual countershaft carried below the main shaft, a quill is mounted below this which carries a differential gear. From this differential two drive shafts provided with universal joints transmit the power to two auxiliary differentials located on the front and rear axles respectively. The differentials on the axles in turn drive the wheels and as the wheels are movable to steer the vehicle, as well as rotatable to drive it, it is apparent that the final drive shafts which transmit power to the wheels must have universal joints to compensate for wheel movement when set at an angle to direct the vehicle.

A section through the universal joints employed at the wheels is clearly shown at *B*, Fig. 177-c. Here it will be seen that the universal joint is a regular double yoke and cross type enclosed in a housing that protects it from the dirt and grit and which permits of considerable movement of the drive shaft without allowing the lubricant with which the universal joint is packed to escape. One end of the universal joint is attached to the drive shaft which runs to the differential on the axle while the other yoke drives a spur pinion which is well supported by a taper roller bearing placed at each side. This spur drive pinion engages with an internal spur gear carried within the body of the wheel and applies the power near the wheel rim, thereby gaining the greatest driving leverage possible. The internal gear of the wheel and the pinion driving it are well housed to exclude grit and retain lubricant and this housing at the same time serves as a brake drum.

The wheels, one of which is shown at Fig. 177-d, are interchangeable. The two drive axles with their universals are duplicates of each other and the three differential gears, consisting of that in the gear box and those on the axle, are all alike. The differential is a special Wayne type which differs from the common construction in that it automatically drives the wheel which has the greatest resistance and which has traction and this feature coupled with the use of four driving wheels makes it possible to propel the truck if any one of the four wheels has traction. It is claimed that while the truck has 120 inches wheel base it will turn in a circle of twenty-two feet radius, which is accomplished by the four-wheel steering feature. There are four ample brakes, one on each

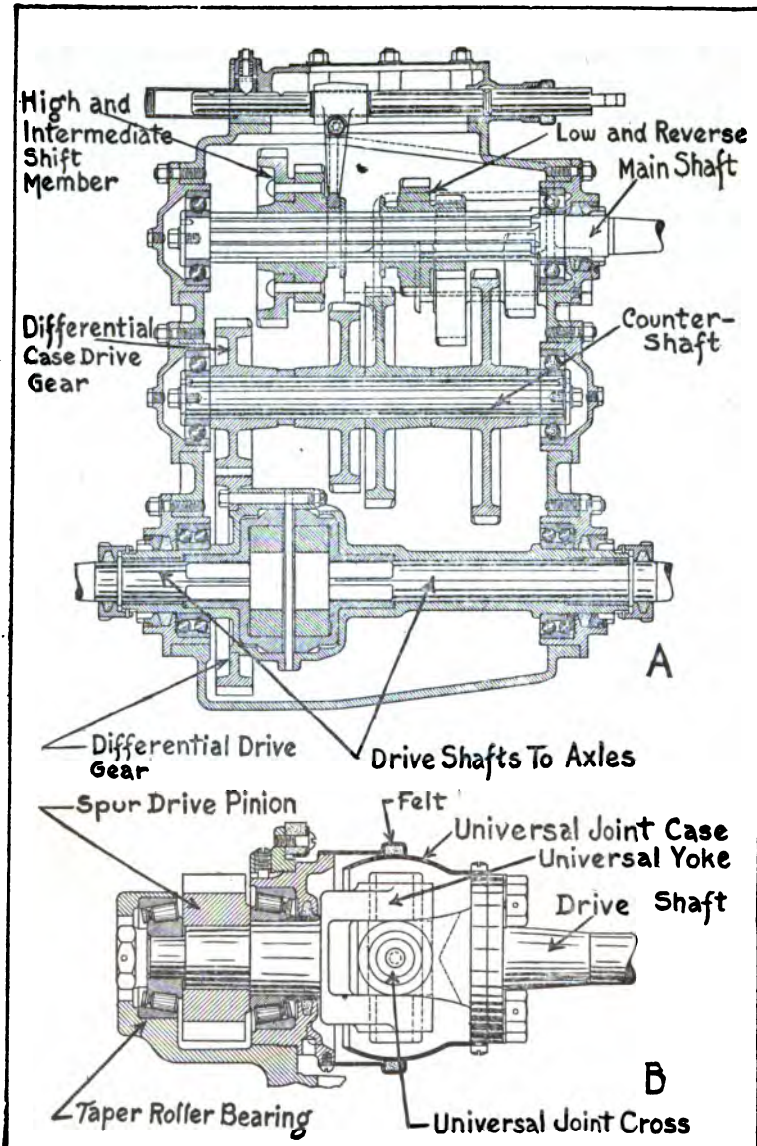


Fig. 177-c.—Components of Distinctive Design Necessary to Successfully Apply the Four Wheel Drive Principle on Rambler Trucks. A.—Section of Four Speed Gearset Having Drive Through Gears on All Speeds and Incorporating a Differential Drive Assembly to Impart Motion to the Axles. B.—Universal Joint Construction Utilized to Drive Wheel.

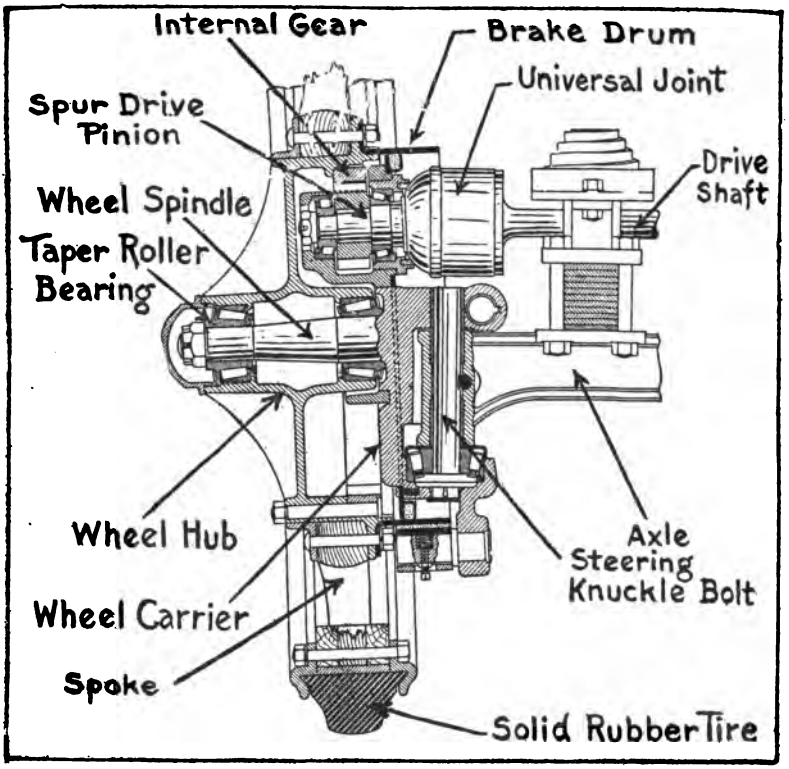


Fig. 177-d.—Type of Wheel Used on Rambler Four Wheel Drive Truck.

wheel, and it is claimed that either set of two brakes is sufficient to hold the loaded truck on a 30 per cent grade. The wheel revolves on taper roller bearings carried by the wheel spindle. The steering knuckle is a special form of the inverted Elliot type and not only carries the wheel spindle but the frame supporting the spur driving pinion as well. The loaded front axle is supported by a taper roller bearing at the lower end of the steering knuckle which makes it possible to turn the wheel with minimum exertion on the part of the operator. When the wheel is moved by the steering knuckle the frame carrying the spur drive pinion turns as well but owing to the universal joint the drive is not interrupted and the wheels are all

driven regardless of whether they are n a stra'ght ahead position or at an angle to steer the car. Other vehicles have been evolved and applied as tractors for fire department service where the drive is through the front wheels only, these members being very similar in construction to the form described.

NOTE.—For further information relative to power transmission see "The Modern Gasoline Automobile." By Pagé.

LESSON TWENTY

DIFFERENTIAL GEAR CONSTRUCTION AND OPERATION

Q. What is a differential gear?

A. A differential gear is a compensating mechanism interposed in the automobile transmission system to permit the traction members or driving wheels to turn at different speeds when describing curves.

Q. Is a compensating arrangement needed on a wagon?

A. The ordinary forms of horse drawn vehicles do not need any compensating arrangement because all wheels are independent of each other and revolve on fixed axles.

Q. What would be the result if no differential gear was fitted to a four wheel automobile?

A. Without a differential gear the ordinary form of motor vehicle would be difficult to handle on curves and all parts of the driving mechanism as well as the tires would be subjected to severe stresses that would produce rapid depreciation.

Q. Where is the differential gear carried?

A. The ordinary form of differential or compensating gear may be incorporated as part of the gear set where this member is attached to the countershaft; as part of a countershaft assembly, even if the gearset is a separate unit, and as a part of a rear live axle if the direct drive system is employed.

Q. Can a practical automobile be made without a differential gear?

A. The only method by which a practical automobile can be constructed and dispense with a differential arrangement is to use but one rear driving wheel mounted in such a way that its point

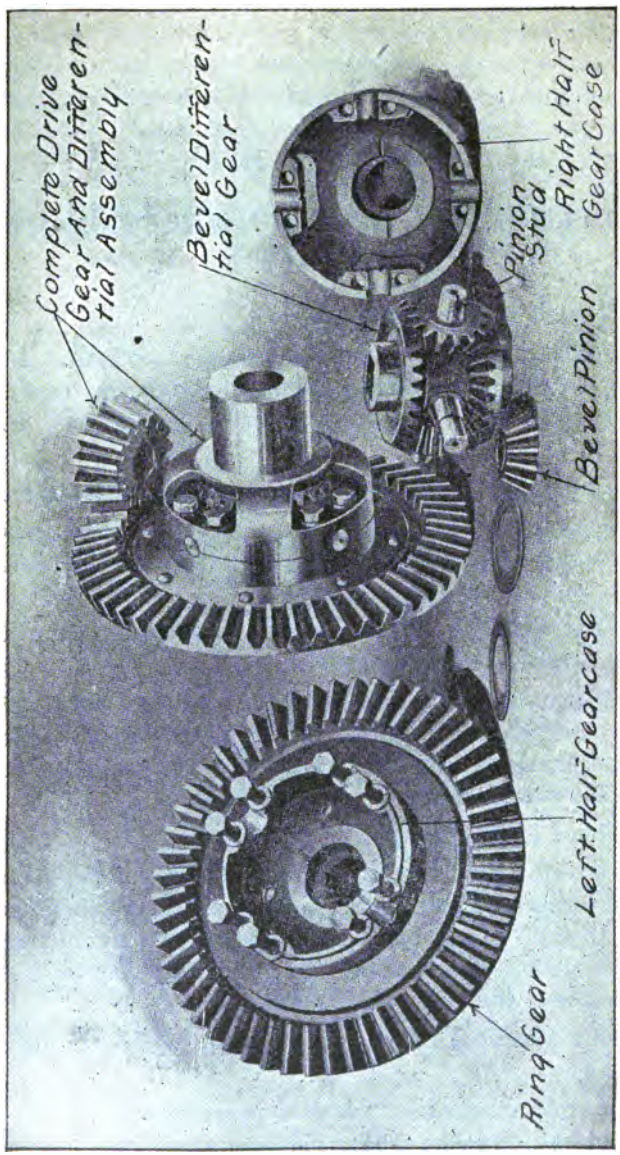


Fig. 178.—Parts of Typical Bevel Gear Differential and Their Relation in a Completed Assembly.

of contact with the ground corresponds to the apex of a triangle, the base line of which is the distance between the points of contact between the two front wheels and the ground.

Q. Describe construction of simplest type of differential gear.

A. The parts of a typical, simple differential gear are clearly outlined at Fig. 178. The gearing is carried in a case composed of two members having suitable openings between the halves of the case to carry the studs on which the bevel pinions revolve. All gearing is mounted inside of the differential casing, and as a rule the assembly is composed of two beveled gears, one being attached to each wheel and from three to six bevel pinions carried by the studs secured to the differential case.

Q. Outline action of simple differential gear.

A. The arrangement of the gearing is such that when the resistance to both road wheels is the same the entire differential assembly rotates as a unit, though as soon as the resistance against one of the traction members is greater than that against the other then the gearing operates to permit the wheel that has the greatest resistance to turn at a lower rate of speed than the other member. When the resistance is the same against rotation of both wheels then the casing revolves at the speed determined by the driving gearing and the bevel pinions remain fixed on their studs so that both bevel gears attached to drive axles are carried around at the same speed. If the tendency of one of the wheels is to revolve slowly, such as the inner wheel does when turning the corner, then the differential pinions will not only be carried forward with the differential gear case but these will revolve on their studs and by running over the face of the bevel gear that tends to revolve slowly they will permit a difference in wheel speed without interruption of drive.

Q. Name two common forms of differential gear.

A. The two types of differential gear generally used are outlined at Fig. 179. That at *A* is the conventional form of bevel differential in which the compensating gearing is composed entirely of bevel gears and pinions. The form shown at *B* is termed a "spur gear differential" because all gearing is of the spur form. The

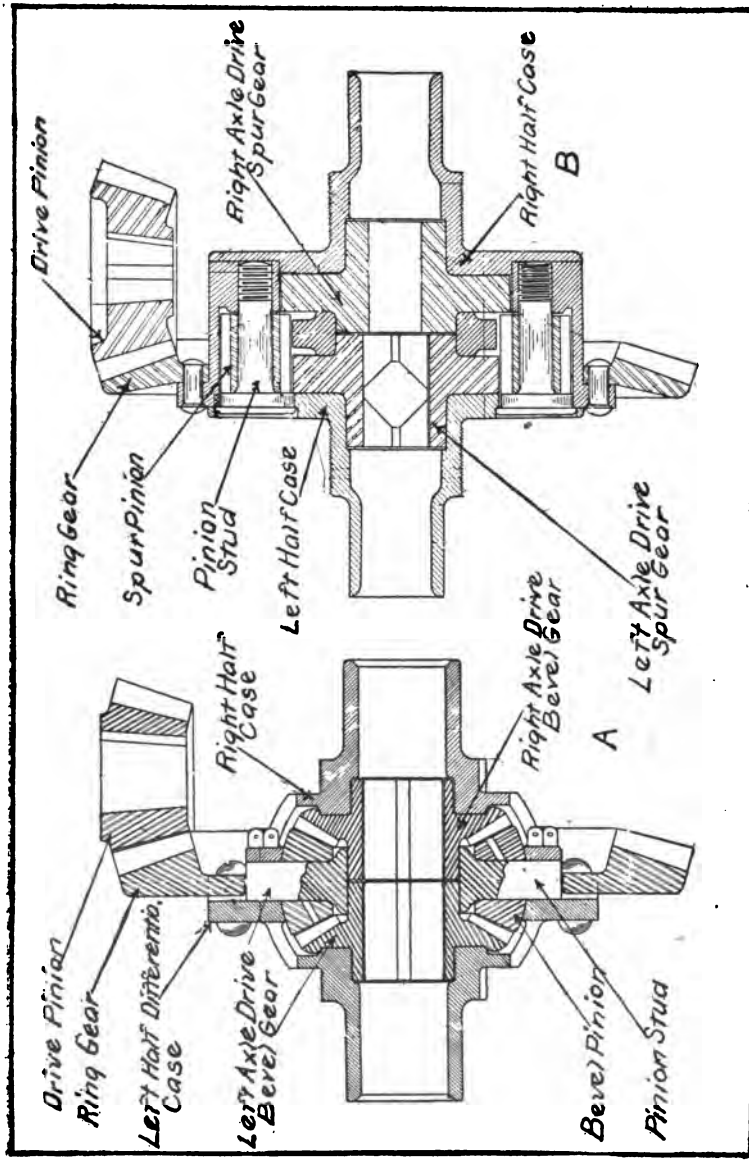


Fig. 179.—Bevel and Spur Gear Differential Compared.

action is practically the same in either case, each driving axle being attached to one of the large gears while the pinions engaging with them are depended on to obtain the differential effect.

Q. Which type is more generally used and why?

A. The bevel gear form of differential has received the widest application because it is simplest in design and the gear teeth can be more substantial and stronger than the corresponding members in a spur differential assembly of equal size.

Q. How many bevel pinions are used and why is it better to use a number of these gears?

A. On light cars a three bevel pinion differential assembly is all that is required, but on heavier cars from four to six pinions are employed. It is advisable to use a large number of gears where the work is severe because the work on any one pinion is lessened as the number of pinions is increased.

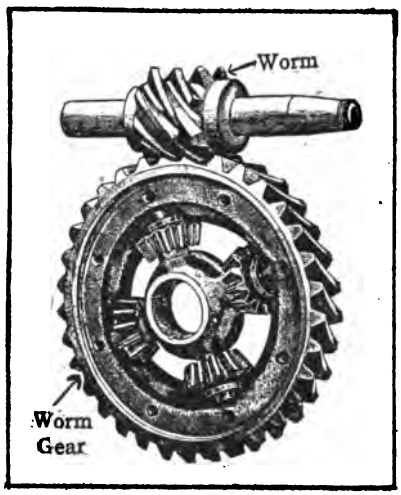


Fig. 180.—Worm Driving Gears Forming Supporting Member for Differential Pinions.

Q. Are there any practical substitutes for the differential gear?

A. Various forms of ratchet and slipping friction mechanisms have been evolved in attempts to replace the differential gear but none of these have proven commercially practical. Differential mechanism comprising cranks and eccentric arrangements have been tried but these are invariably more costly and cumbersome than the gear forms.

Q. Where is the driving sprocket or gear attached to the differential assembly?

A. The driving sprocket or gear, when this is a separate member, is always attached to the case which carries the studs on which

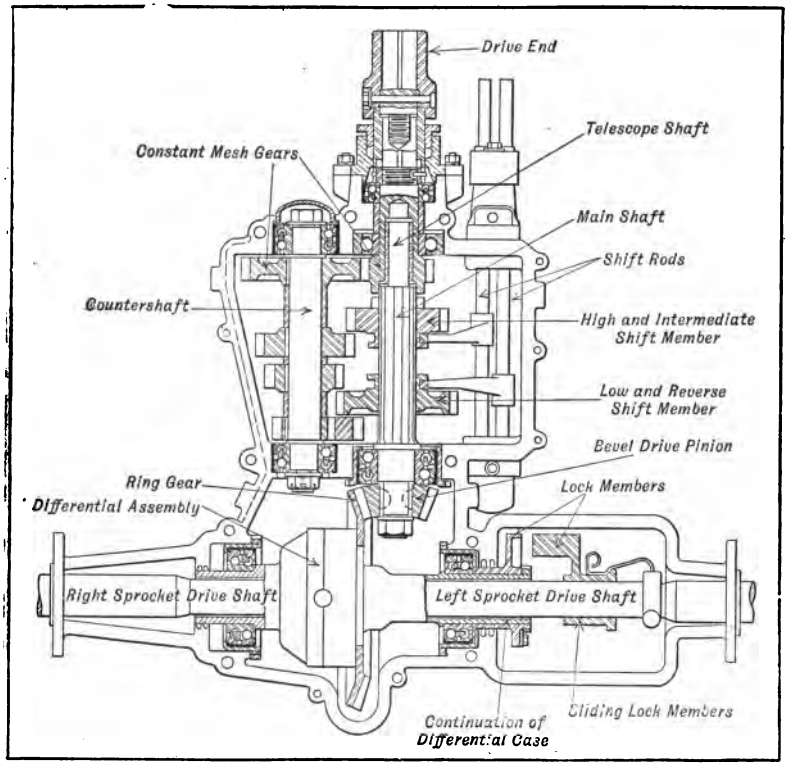


Fig. 181.—Gearset and Differential Assembly of Motor Truck Showing One Method of Locking Differential Gearing So the Differential Assembly Will Turn as a Unit.

the differential pinions revolve. In some cases, as outlined at Fig. 180, where a worm gear is used for driving it is possible to carry the compensating pinions on studs inserted directly in the interior of the gear rim.

Q. Are there any conditions where differential gear action is not desirable?

A. In some cases the differential gear action proves to be a disadvantage. For example, if one of the driving wheels is in mud or other material offering but little traction, and the other wheel is on dry hard road surface, there will be so great a difference be-

tween the resistance of the member on the hard surface and that in the mud that the differential gear will permit the member on the hard surface to remain absolutely stationary while the wheel in the mud hole revolves at a high rate of speed without producing movement of the vehicle. With ordinary forms of light and medium weight pleasure cars, this condition is not so apt to materialize as with heavier vehicles.

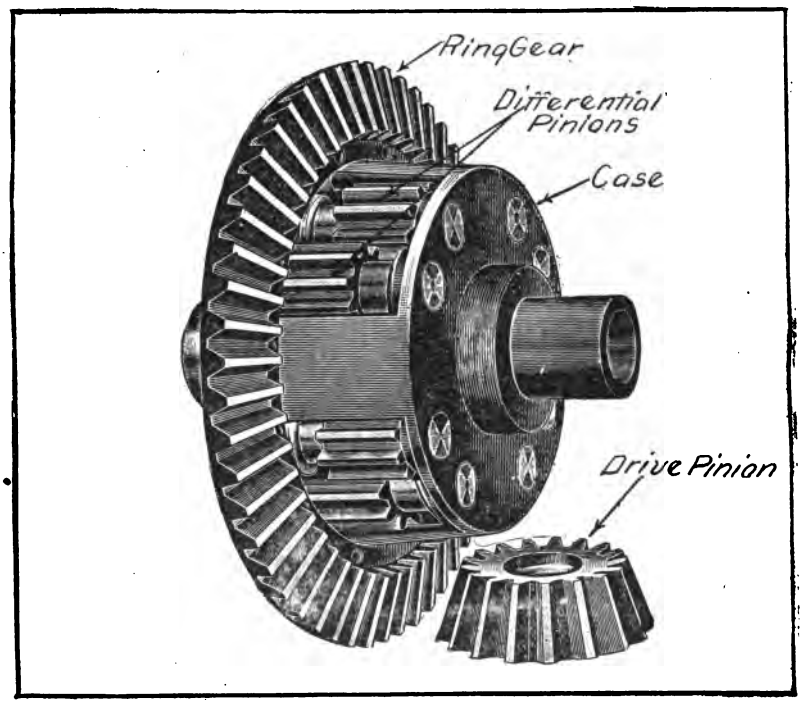


Fig. 182.—Spur Gear Differential Assembly Adapted for Bevel Gear Drive.

Q. Is there any way to put the differential gear out of action in such an emergency?

A. Some vehicles are provided with a mechanism for locking the differential gear together to form a solid unit and deliver the power to both wheels so these must turn in unison. A construction of this kind is outlined at Fig. 181 where it is mounted as a part

of the countershaft assembly of a motor truck. The locking device is very simple, consisting of a jaw or clutch member keyed to and revolving with an extension of the differential case. On the drive shaft extending through the differential member is mounted a sliding lock member which is keyed to the shaft so that it must turn with it. If it is desired to put the differential gear out of action, as might be desirable if one of the driving wheels became mired, the sliding lock member could be pushed into engagement with the fixed member on the continuation of the differential case and the differential mechanism would then revolve as a solid unit as there would be no possibility of the gears working.

Q. What types of vehicles are provided with differential lock?

A. Differential locking mechanism is usually provided only on the heavier classes of self-propelled vehicles, such as motor trucks, gasoline road rollers and agricultural tractors.

LESSON TWENTY-ONE

REAR AXLE TYPES

Q. What are the functions of the conventional rear axle?

A. The ordinary automobile rear axle must not only support the weight of the rear end of the car but usually carries the traction members or driving wheels and the brakes or retarding elements.

Q. What are the two common types of rear axle?

A. Rear axles may be divided into two general classes, termed "dead" and "live" constructions respectively.

Q. Describe the construction of a "dead" rear axle.

A. This form of axle which is outlined at Fig. 183 is practically the same in general construction as the rear axle used on horse drawn vehicles. It is composed of a stationary member, either of tubular or solid section, which is attached to the springs by suitable spring pads or chairs and which is provided with a spindle at either end on which the wheels revolve. The wheel hubs are independent of each other and are each driven by direct chain connection with a sprocket on a countershaft member carried by the frame.

Q. On what types of vehicles is a "dead" axle commonly used?

A. As the non-rotating axle construction may be made very strong without increasing its size to any extent, it is commonly applied to vehicles intended to carry heavy loads that need a double reduction drive.

Q. Where is the differential gear mounted when a "dead" rear axle is employed?

A. The differential gear must be used in connection with a stationary axle but it is usually incorporated in the countershaft assembly carried by the frame.

Q. How are the wheels driven when mounted on a stationary axle?

A. The wheel hubs are provided with sprockets which are connected to smaller sprockets carried by the axle shafts of the countershaft assembly by means of chains which transmit the power to each rear wheel.

Q. What is the advantage of this method of construction?

A. On heavy vehicles, such as motor trucks, which are designed to operate on solid rubber tires, it is desirable to suspend as much of the mechanism of the car as possible from the frame so the springs may absorb the larger portion of the jarring and jolting due to solid tires. As most of the heavier vehicles are designed to move slowly it is necessary to employ a double reduction system so the differ-

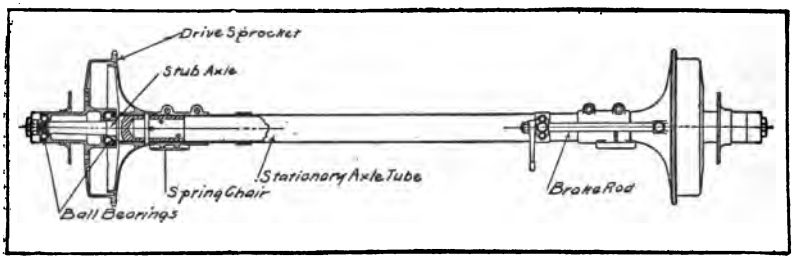


Fig. 183.—Simple Automobile Rear Axle of the "Dead" Type.

ential and bevel gear drive assembly which provides the first speed reduction is part of the countershaft and the rear axle which must be strong and yet relatively light is called upon only to carry the car weight and not to transmit any of the engine power. Another reduction of speed is possible in addition to that obtained at the countershaft by making the driving sprockets smaller than the driven members carried by the wheel hubs. Owing to the use of a fixed rear axle member it is not necessary to carry any of the more or less delicate mechanism forming the differential and drive gearing as part of the axle and these portions of the drive system may be carried in a separate assembly attached to the spring supported frame members.

Q. Describe construction of simple type live axle.

A. A simple live axle of conventional design is outlined at Fig.

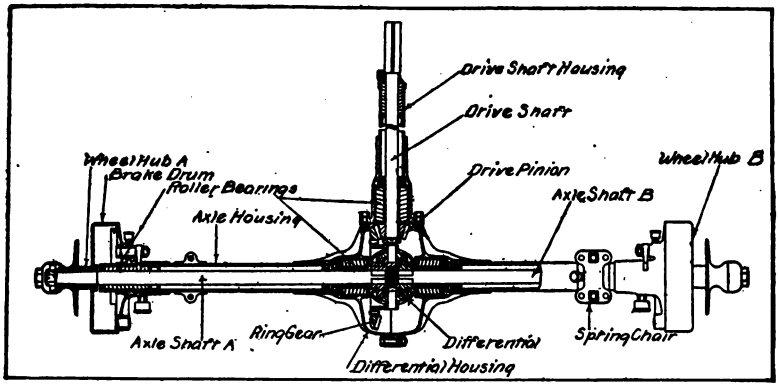


Fig. 184.—"Live" Automobile Rear Axle of Bevel Gear Drive Type.

184. This member not only supports the weight of the car, but also incorporates the power transmission and differential gearing. The power is taken from the gearset through a drive shaft revolving in roller bearings. At the end of the drive shaft a bevel pinion is secured which meshes with a bevel or ring gear carried by the differential housing. The differential assembly is also supported on roller bearings and shafts extend from the differential gears to the wheel hubs. All the rotating parts are housed, the differential and bevel gear assembly being mounted in a housing of malleable iron while the drive shaft and axle shafts *A* and *B* are protected and supported by a tubular axle housing, which is securely attached

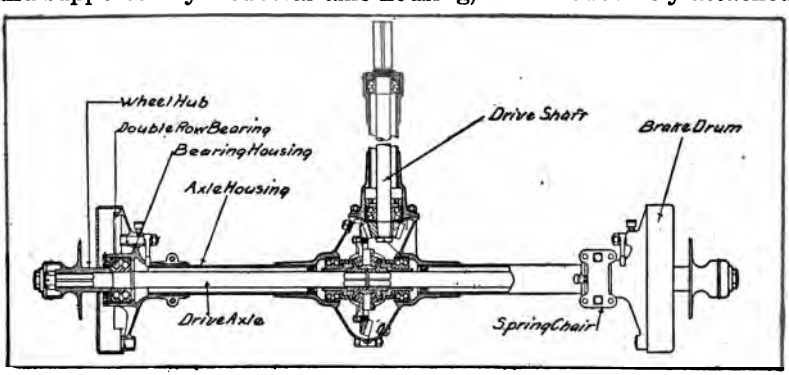


Fig. 185.—"Semi-Floating" Automobile Rear Axle Construction With Shafts and Gearing Mounted on Double Row Ball Bearings.

to the differential housing at the center of the axle. In the simplest form of live axle construction the axle shafts not only transmit the power from the differential gears to the hubs but are called upon to carry the car weight at the rear end as well. This form of construction is suitable only for light and medium weight cars.

Q. How many types of live axle are used?

A. Live axles may be of a simple form, as previously described and shown at Figs. 184 and 185, or they may be of a semi-floating or full floating construction. The simple live axle shown at Fig. 185 is practically the same in construction and method of operation as that previously outlined with the exception that the axle shafts are carried on annular ball bearings instead of roller bearings.

Q. What is the "semi-floating" axle?

A. The term "semi-floating" is applied to those forms of axles where the axle shaft is depended on to drive the wheels as well as take part of the load caused by thrust reaction, when the wheel skids sideways. An axle of this general form is outlined at Fig. 186, and it will be noted by comparing it with the form shown at 184 and 185 that the wheel hub is carried by a large bearing that is mounted on the drive axle housing so the axle shaft that is fastened in the wheel hub is not called upon to carry any of the car weight. It is, however, depended on to steady the wheel against side thrust. This form of axle construction is often called "the one bearing floating axle" because for all practical purposes it is a floating type inasmuch as the axle shaft may be withdrawn from the interior of the axle housing or the differential assembly removed without relieving the wheels of the car weight.

Q. What is the "full floating axle" construction?

A. The full floating rear axle construction, which is depicted at Figs. 187 and 188, differs from the preceding form inasmuch as the wheel hub is carried by two bearings which are in turn supported by the fixed housing member through which the drive axle passes. The driving axle is a floating member that is called upon only to transmit power and not to take any of the car weight. In the simple live axle forms the axle shaft revolves in bearings carried by the interior of the housing and as the wheels are secured to the shafts

supporting car weight these are subjected to much more strain than floating shafts.

In the true floating axle the drive axles may be removed by taking off a hub cap and pulling out the shaft. The wheel hub is not disturbed and the differential gear may be removed if desired without disturbing the wheels. In the live action construction of the simple form, the axle shafts can be taken out only by taking the entire axle assembly apart as outlined at Fig. 189. This means that the rear end of the car must be jacked up and the axle removed from the chassis in order to take it apart. The big advantage of the floating construction, especially in the forms shown at Fig.

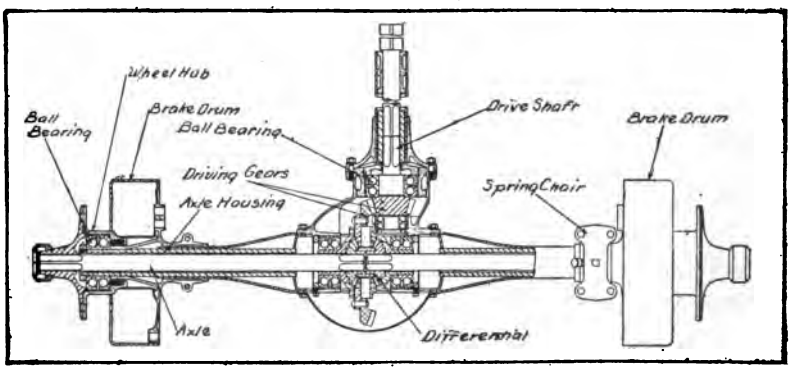


Fig. 186.—Typical "Three-Quarter Floating" Rear Axle Having Driving Wheels Supported by One Double Row Bearing in Each Wheel Hub.

186 and 188, is that the differential and drive gear assembly may be removed for inspection or adjustment without disturbing the axle housings or taking wheels off. The axle shown at Fig. 187 utilizes double row ball bearings at all important points while that outlined at Fig. 188 employs single row ball bearings to carry the radial or direct acting loads while the end thrust caused by the bevel drive gears is taken by a ball thrust bearing used in combination with a single row at the ring gear side of the differential assembly.

Q. How are the rear wheels driven in a simple live axle?

A. The rear wheel hubs are usually provided with key ways which engage with driving keys carried by the live axle and are

kept from coming off either by means of pins passing through the hub and the shaft or by a clamping nut which forces the wheel tightly on the taper end of the live axle shaft.

Q. How are the wheels driven in a semi-floating axle?

A. The wheels of a semi-floating axle are driven by squared ends of the drive shafts which are a tight fit in a flanged member securely bolted to the wheel hubs. In some forms of axles the driving flange is formed integrally with the axle shaft and is securely bolted to the hub.

Q. How are the wheels driven in a full-floating axle?

A. When the full-floating construction is employed the live

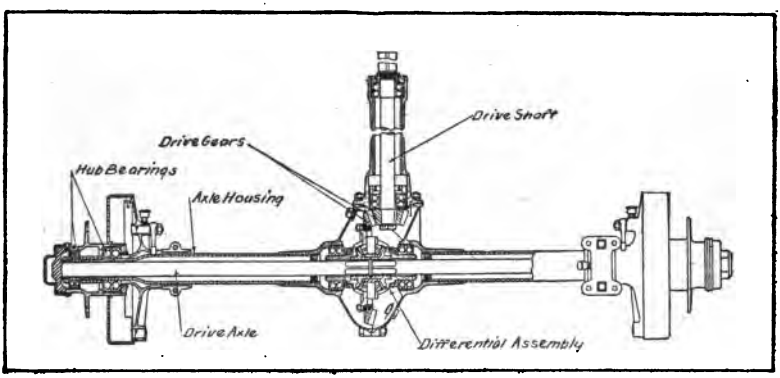


Fig. 187.—"Full-Floating" Bevel Gear Drive Axle Having Driving Wheels Mounted on Two Ball-Bearings With All the Car Weight Carried on the Drive Axle Housing Tubes.

axle shafts carry positive driving clutch members of the male form which engage with a corresponding female member forming part of the wheel hub. The axle shaft is kept from working out by means of a threaded hub cap, as shown at Fig. 188.

Q. What is a combined live and dead axle construction?

A. Some designers endeavor to secure the advantages of the stationary form of axle and yet have the driving gears carried by the axle by using a combination construction in which a non-rotating member serves to carry the car weight while a live axle is attached to the fixed member and carries the differential gear

and bevel gears. The wheels which revolve on the fixed axle are driven from the live portion by means of spur gears engaging corresponding members attached to the wheel hubs. Such a construction is not generally used because most engineers contend that this places too much unsprung weight on the rear axle.

Q. What is a double reduction live axle?

A. A double reduction axle is one where the engine power is taken by compound gearing instead of the simple bevel or worm gearing ordinarily used. For example, the power from the gear set may be first delivered to a pair of bevel gears, the driven member of which is carried on a countershaft which also carries a spur pinion designed to mesh with a large spur gear on the differential

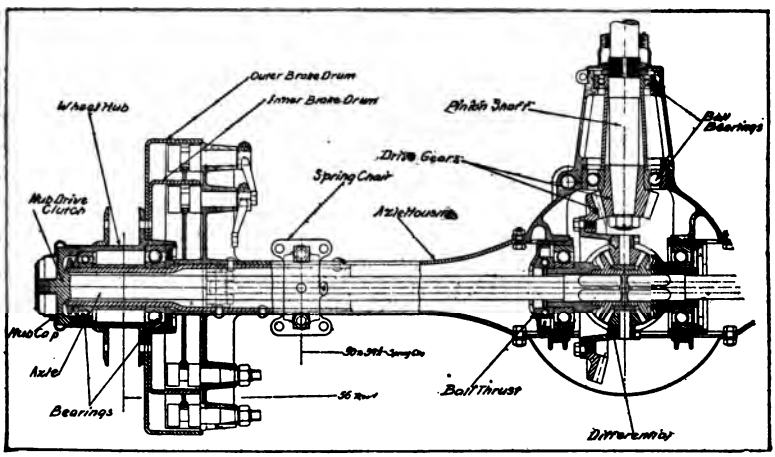


Fig. 188.—McCue Rear Axle of "Full-Floating" Type Showing Use of Single Row Ball-Bearings at All Points.

case. This provides two speed reductions, one between the driving gear on the transmission shaft and the member with which it engages on the counter and a further reduction in speed between the other two driving gears.

Q. What is a two speed direct drive axle and what are its advantages?

A. This is an axle construction of recent development and is called the two speed direct drive axle because in place of a single

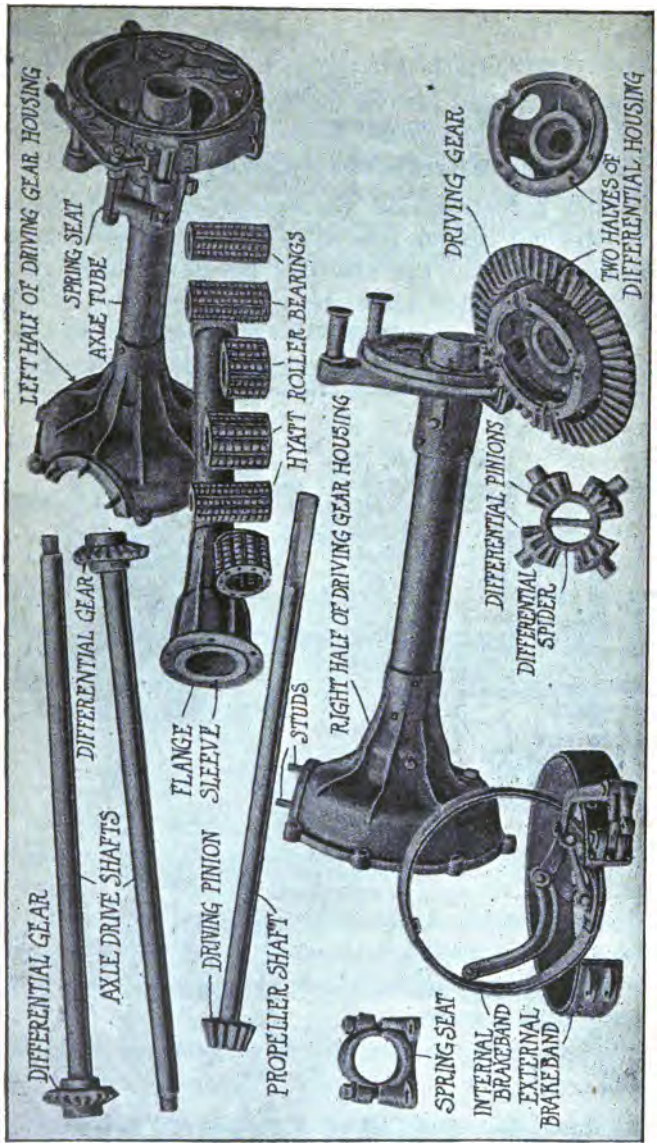


Fig. 189.—Typical Simple Live Axle Construction Taken Apart to Show Components and Method of Disassembling Axles of This Form.

bevel pinion and ring gear used in the ordinary construction, there are two bevel pinions and two ring gears attached to the differential casing. A typical assembly of this nature is shown at Fig. 189-a. The drive pinion *B* is integral with the drive shaft and always revolves with it while the larger drive pinion *A* only revolves with the drive shaft when the sliding clutch *A* is engaged with the corresponding clutch member attached to the pinion. When the sliding clutch *A* is shifted into position, the actuating bell crank shifts another sliding clutch attached to the differential gear case which releases ring gear *B* and allows the engine to drive the differential casing and the gearing it contains through the medium of drive pinion *A* and ring gear *A*.

When the other ratio is desired the positive clutch shifting lever is moved so that it brings sliding clutch *A* out of engagement which causes a simultaneous movement of sliding clutch *B* so that ring gear *B* is clutched to the differential casing. It will be apparent that the drive is through only one set of gears at a time, the set that is not in use revolving idly on suitable bearings. This construction affords two gear ratios, each driving direct from the engine to the wheels without any intermediate gearing other than the regular driving gears ordinarily employed in a one speed axle.

It is contended that no one single gear ratio can be just right for all vehicle speeds and all road conditions. The usual gear ratio of a single direct drive axle ranges from 3.5 to 1 to 4 to 1 according to the weight and power of the car. If a car is geared low, high speeds can only be obtained by racing the engine but its hill climbing abilities on the high are excellent. At the other hand, if the gear ratio is such that the car can be operated at high speed without racing the engine it will be a poor hill climber and the low gears will have to be resorted to on any gradient of magnitude. In the axle shown there are two gear ratios, one of which is low, and which is especially adapted for city driving where starting, stopping and slowing down are frequent and where cautious operation is necessary. When conditions are more favorable, the higher direct drive gearing may be brought in action and higher vehicle speeds are possible without a corresponding increase of engine revolutions.

For example, with the lower direct driving gears in operation,

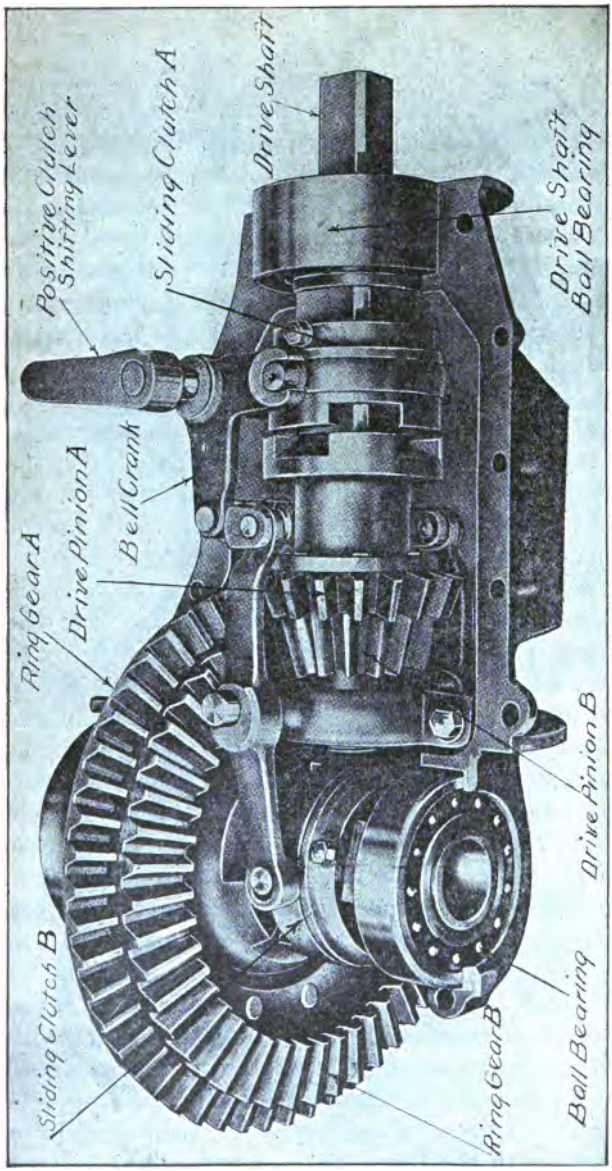


Fig. 189a.—View of Austin Two-speed Rear Axle, Showing Two Pair of Bevel Drive Gears and Positive Clutches by Which Either Gear Ratio May be Brought In Action

an engine speed of 700 revolutions per minute would mean a car speed of approximately 20 miles per hour, whereas if the high direct drive gears are used the car will travel approximately 30 miles per hour with no increase in engine speed. This increase in car speed without a corresponding increase in crank shaft revolutions means that there is a decrease in fuel consumption for a given mileage. A given quantity of gas is utilized to greater advantage and produces more actual power at the rear wheels than with the engine turning over more rapidly on the low gear ratio. Friction and wear of power plant and transmission gearing is also materially reduced because the parts are operated more slowly. When a low gear ratio is employed a car will vibrate very much at high vehicle speeds on account of the great speed at which the motor is operating, while with the higher ratios there is comparative freedom from vibration because the power plant is not operated at excessive speed.

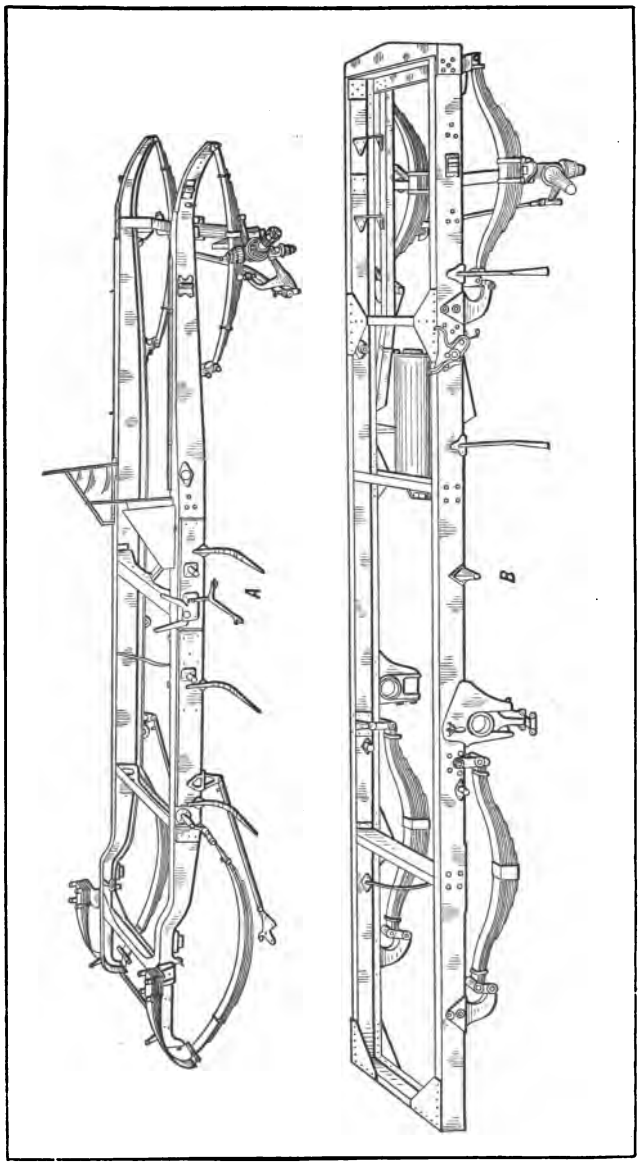


Fig. 190.—Construction of Conventional Automobile Frames. A—Pleasure Type. B—Frame Structure for Motor Trucks.

LESSON TWENTY-TWO

AUTOMOBILE FRAMES AND SPRINGS

Q. What is the function of the frame?

A. The frame of the automobile forms the basis of the entire mechanism. It not only supports the power plant, change speed gearing, body and controlling devices but also serves as a tie member between the two axles and carries the springs by which these members are joined to the frame.

Q. What factors determine size of frame to be used?

A. The size and construction of the frame depend entirely upon the class of vehicle to which it is fitted. Some motor cars require frames of great strength and light weight while others can use heavy frames.

Q. What materials are used in frame manufacture?

A. Automobile frames may be made of wood or metal, or combinations of these materials. When metal is used the frame members may be of tubular or channel section steel, of iron angles or channels, or it may be a composite structure using tubing and pressed steel parts in combination. The two typical forms of metal frames with the various running board irons, spring supports, etc., in place are outlined at Fig. 190. That at *A* is used in pleasure car service while the form at *B* is a heavier construction intended for commercial car use.

Q. What type of car uses frames made of structural steel?

A. Structural steel channels in standard sizes are commonly used in heavy commercial vehicles.

Q. Describe various methods of using wood.

A. The frame may be composed of wooden beams or of composite members made from various laminæ glued and screwed to-

gether or of lighter wood sections reinforced with a strip of iron or steel extending the full length of the piece.

Q. On what type of vehicles are armored wood frames used?

A. Composite frames of wood and metal are seldom used except on heavy vehicles such as motor trucks. The feature of this method of construction is that a strong and yet light supporting member is employed, the strength being derived from the steel reinforcing plate. The wood frame does not transmit vibration as do metal frames and the machinery is better protected from the vibration incidental to vehicle operation on poor highway surfaces than when the shock transmitting all metal frame is employed.

Q. What are the features of laminated wood frames?

A. The laminated wood frame structure is one that possesses great strength without being heavy, which enables this type of frame to be employed in pleasure car use. A laminated frame is not liable to warp or check and the arrangement of the various pieces comprising the frame is such that the arrangement of the wood fibers makes for great strength. When wood is employed as frame material ash is generally used because of its superior strength and lightness. A laminated wood frame is said to be stronger than a pressed steel frame of equal weight, and as the wood absorbs instead of transmitting vibration it is contended by those favoring wood frame construction that the machinery is better protected from road shock than when all metal frames are used.

Q. Why is pressed steel used so widely in automobile frame construction?

A. Pressed steel has received general application in automobile work because the frame side and cross members may be quickly and economically formed into shapes that would not be possible with any other material. Side members may be cambered or upswept which would not be possible if wood is used and a frame of superior lightness to that made of standard structural shapes may be evolved by the designer. Pressed steel frames may utilize members best adapted to support the various parts, which enables the designer to adapt the frame to the components to be supported rather than design all parts to fit a frame. Pressed steel frames are

light, cheap and strong if properly designed and are especially adapted to quantity production.

Q. What are the advantages of upswept side members?

A. When a frame is upswept at the rear, as shown at Fig. 190, it is possible to use types of springs that have great flexibility of movement without raising the center of gravity of the car to a point where side sways might become dangerous. A frame may be upswept at both front and rear ends and the body carried closer to the ground than if straight frame members were used without sacrificing ease of riding and ample axle and spring movement.

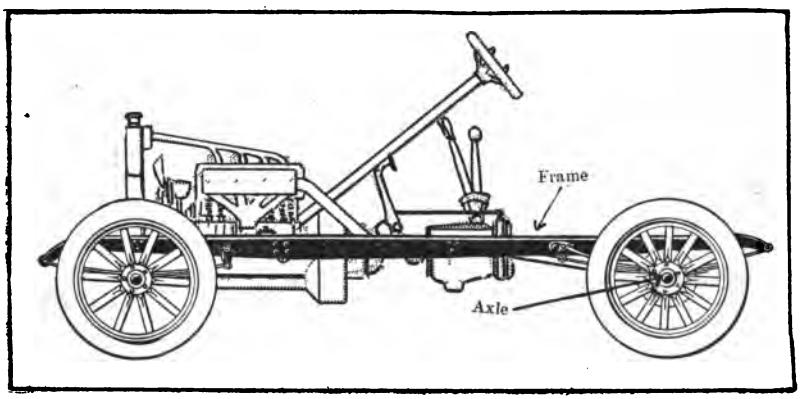


Fig. 191.—Usual Method of Frame Support in Which Weight is Carried by Springs Placed Over the Axle.

Q. What are the reasons for using inswept or cambered members?

A. Many automobile frame side members are cambered or swept in at a point approximately below the dash so the front portion of the frame is narrower than the other parts. The object of narrowing a frame at the front end in this manner is to provide a greater degree of front wheel movement and permit a car to turn in smaller circles than would be the case if the front wheels were moved only to the angular limits permitted by a wide frame. Another advantage of the cambered member is that it permits the motor to be attached directly to the frame, and thus eliminates a subframe to carry the power plant.

Q. Is the frame always carried above the axles?

A. Automobile frames are not always carried above the axles as shown at Fig. 191 as in some cases the frame may be underslung or carried below the axles, as shown at Fig. 192.

Q. What are the advantages of the underslung frame?

A. Where the frame is carried beneath the axles, the center of gravity is brought lower and it is possible to turn corners at higher speeds than with cars having the frame carried over the axles. An advantage of having a smooth underframe, which can be thoroughly encased with a dust pan and present a smooth outline, is that less dust is created and that the vital parts, such as the motor flywheel, gearcase, etc., are protected against injury should the wheels sink

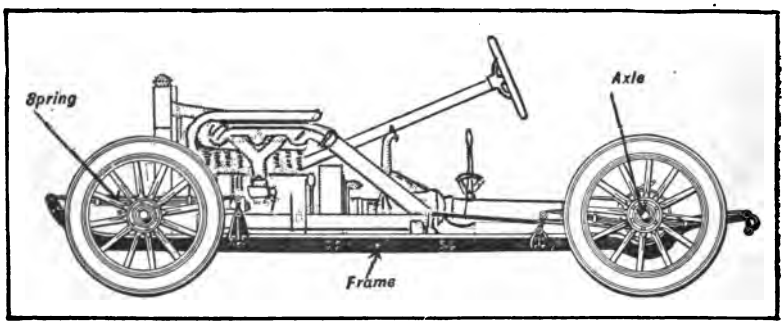


Fig. 192.—Underslung Frame Showing Method of Supporting From the Axle.

into a mud hole or in a deep rut. It is contended also that the underslung construction provides greater accessibility to the working units of the power plant and transmission. Another superiority of the underslung frame is said to be easy riding, because side sway is largely eliminated by suspending the frame from the springs instead of balancing it upon the springs. As the center of gravity is carried lower the car must be tipped to a greater angle in order to overturn it. This can be clearly shown by drawings at Fig. 193, which shows a test made to obtain the relative stability of the overslung and underslung types. A block and tackle equipment was employed at one side of the car, so that two wheels could be raised to

just a height where the car would still stand poised on the two wheels on which it rested.

The experiment made with the conventional construction outlined at *A* demonstrated that when the car was tipped so that a line joining the bottoms of the two wheels was at an angle of 43 degrees with the ground that the car would tip over. When the same experiment was tried as shown at *B* with an underslung car it was demonstrated that the car could be tipped to an angle of 55 degrees without becoming overbalanced. These tests would indicate that there is a considerably greater degree of safety when

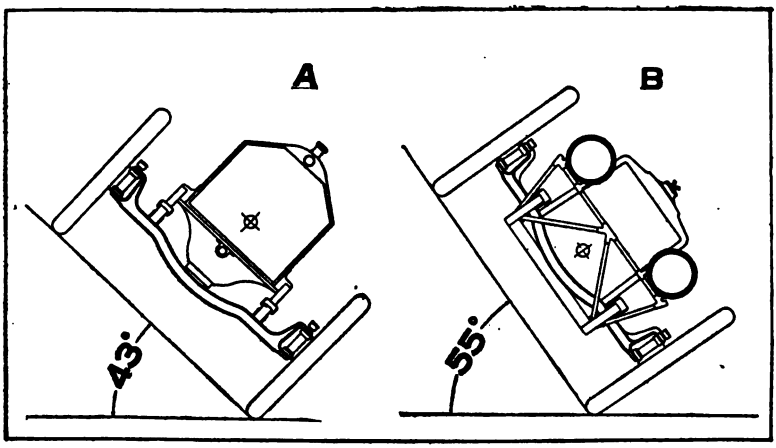


Fig. 193.—Comparison to Show Relative Stability of Two Types of Frame Suspension. A—Angle at Which Overhung Car Ceases to Be in Stable Equilibrium. B—Angle to Which Underslung Car May Be Tipped Without Danger of Overturning.

the underslung frame is used as compared to the conventional method of construction.

Q. Describe construction of typical frame made of pressed steel.

A. A typical frame of the pressed steel form consists essentially of two side members joined together by means of cross members which act as spacers to separate the two frame sides, as well as form a supporting means for the power plant and transmission elements. It will be noted at Fig. 190-A the one piece frame sides

are joined by four cross members, one at the front practically over the front axle, which serves as a radiator support, two at the intermediate points in the frame under the body and a fourth at the rear end. The cross members are well braced with gusset plates or triangular pieces of pressed steel in order to stiffen the construction. Some forms of frames have a shorter inner member or sub-frame carried between the two side members.

Q. What is the sub-frame for?

A. The sub-frame is employed to support the power plant and change speed gearing when the main frame side members are too far apart to permit these units being attached directly to the frame sides.

Q. How are the springs attached to a frame?

A. The springs are attached to special spring horns or brackets securely riveted to the frame side members.

Q. How are running board supporting irons, radius rods, spring end brackets and other parts attached to the frame?

A. The usual method of attaching auxiliary parts not likely to be removed to the frame is by some permanent means of securing as by riveting.

Q. Name common types of springs.

A. The common forms of springs utilized in motor car construction are the helical coil and laminated leaf forms.

Q. Where are coil springs used in automobile construction?

A. Coil springs are generally employed in various parts of the mechanism such as on the valves, in the clutch and to return various rods or operating levers to their proper position when released. Some forms of automobiles have been made in which coil springs were utilized as supporting mediums for the frame but these have not been generally used on account of various structural defects.

Q. Why are laminated leaf springs so generally used?

A. When the laminated leaf construction is employed it is possible to so proportion the springs that members having great strength and resiliency are used and the strength may be varied easily by using different numbers and widths of leaves. If one of

the spring leaves should break the member is still serviceable, whereas if one of the coils of a helical spring breaks the member can be used no longer. Coil springs are especially desirable where quick action is required and it is because of this quality that they are employed as valve springs and in motor car seat cushions or where great strength is needed in small space, which is the reason that coil springs are used in clutches. The springs used for frame suspension must be more gradual in action and it is for this reason that the leaf form is preferred because in the few cases where coil springs

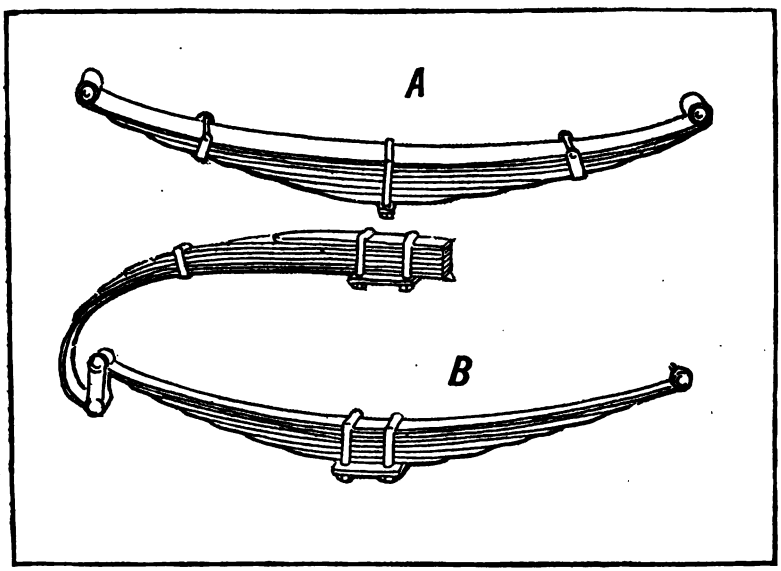


Fig. 194.—The Two Most Popular Forms of Automobile Springs. A—Semi-Elliptic Type. B—Three-Quarter Elliptic Forms.

have been used their action had to be dampened or retarded by means of friction shock absorbers or other devices of that character.

Q. Name principal types of leaf springs.

A. Leaf springs used for supporting automobile frames are either of the semi-elliptic, three-quarter or full elliptic type; or the platform spring, which is a composite form composed of three semi-elliptic members.

Q. Describe construction and state advantages of semi-elliptic springs.

A. The semi-elliptic spring is shown at Fig. 194-A and as will be noted it is composed of a number of strips of steel graduated in length so the longest member is at the top and the shortest member is at the bottom. The upper leaf is turned over at the ends to form eyes by which the spring is attached to the frame and the other leaves are held to the top leaf or main member by means of small clamps. The semi-eliptic form of spring is suited for carrying great weight and is well adapted for use at points where a stiff suspension is desired.

Q. What are three-quarter and full elliptic springs and why are they used?

A. A three-quarter scroll elliptic spring is shown at Fig. 194-B. This member is composed of a semi-elliptic spring and an auxiliary member which is a quarter elliptic spring secured to one end of the lower member by means of a spring shackle. The free end of the upper member is attached to the motor car frame, as is the free end of the semi-elliptic or lower member. A full elliptic spring is composed of two semi-elliptic members joined together either in the manner indicated for the three-quarter elliptic as outlined at B, or by inverting one member and have it fit into suitable sockets at the ends of the other member. The advantage of the full elliptic and three-quarter form is greater flexibility on account of the construction permitting greater spring movement than is possible with the semi-eliptic form of the same length.

Q. What is the platform spring suspension?

A. Two forms of platform springs are shown at Figs. 195 and 196. The platform spring consists of three semi-elliptic members, two of which are placed parallel with the frame side members while the other is placed at the rear end of the frame parallel to the cross member. The front end of the side springs are secured to the frame, they are attached to the axle at their center and to shackles carried by the cross spring ends at the rear. The frame is supported by one point at the center of the rear cross member which rests at the top of the arc of the cross spring. The cross spring shown

at Fig. 195 is used on a pleasure car chassis and it will be noted that the frame side members are raised directly over the axle in order to permit the proper degree of axle movement. The heavier construction outlined at Fig. 196 shows the application of a platform spring assembly to the frame and axle of a motor truck.

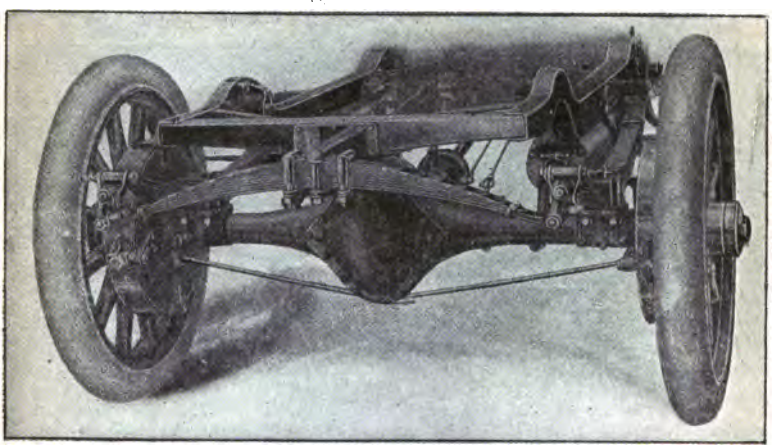


Fig. 195.—Showing Platform Spring Suspension of Rear End of Cadillac Car.

Q. Outline the conventional spring suspension system.

A. As a rule the front end of the car is supported on semi-elliptic springs while the rear end may be carried on three-quarter elliptic, as shown at Fig. 190-A, or by full elliptic or by the platform spring as shown at Figs. 195 and 196. On some heavy commercial car frames, as shown at Fig. 190-B, semi-elliptic springs are utilized at both front and rear of the frame, though in most forms of pleasure cars the semi-elliptic springs are utilized only at the front end.

Q. Why are semi-elliptic springs desirable for supporting front ends of frame?

A. On account of the front end of the frame carrying the power plant and also having the front axle, which is depended on for steering the car, attached to it, it is not desirable or necessary to have great flexibility at that point. The semi-elliptic forms carry

the weight with minimum side sway, serve to hold the front axle steady, and while it does not permit much motion up and down it still possesses sufficient flexibility so the mechanism is not jarred enough to harm it.

Q. Describe a compound spring and state its advantages.

A. A compound spring is a form in which various members are

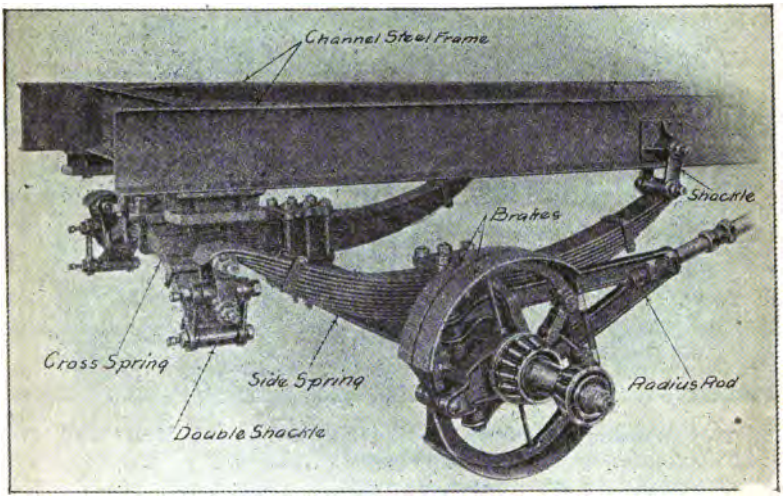


Fig. 196.—Rear End of Heavy Motor Truck Frame Showing Substantial Platform Spring Suspension.

joined together so they may be brought in action progressively as the loads increase and as greater spring strength is desired. The construction of the rear end of a typical three-quarter elliptic spring of the compound form is shown at Fig. 197. Under light loads the more flexible member of the lower spring, which is the longest, and the shortest member of the upper spring are utilized and when the loads increase the other members are brought into service progressively. A compound spring is said to produce as easy riding when a car is not fully loaded as when it is filled with its full complement of passengers. With the ordinary spring suspension designed to carry maximum weight stiff action may result if the car is not loaded to capacity. With a compound spring only certain portions of it

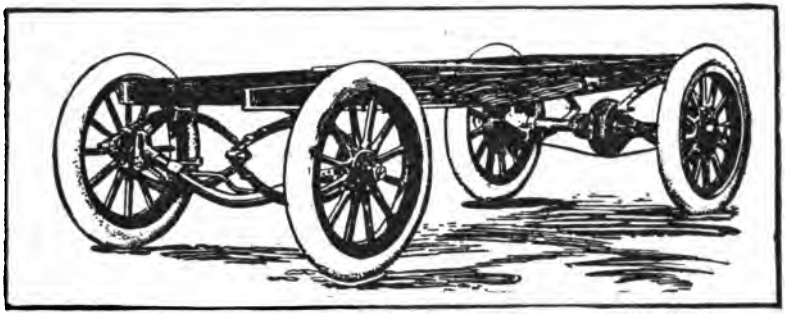


Fig. 196A.—Franklin Wood Frame Supported by Full Elliptic Springs at Front and Rear.

are brought in action when the loads are light, the entire spring being used only under conditions where maximum strength is needed.

Q. How is spring strength obtained?

A. The strength of leaf springs is determined by the width and thickness of the laminæ, the number used and the material of which they are composed.

Q. How is spring flexibility secured?

A. A spring is made flexible by using long and thin plates and by employing as small a number as possible.

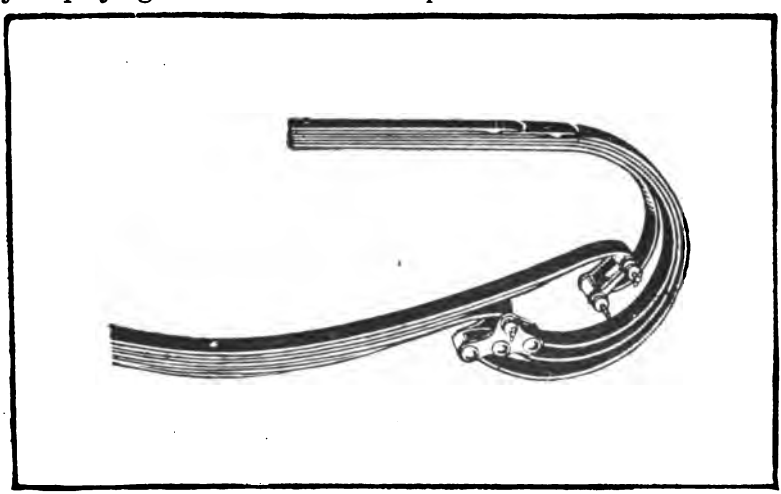


Fig. 197.—Compound Spring Structure.

Q. How are springs attached to axles?

A. The method of securing semi-elliptic springs to front axles is clearly shown at Fig. 198. They are held by means of U clips which straddle the spring at its center and which bolt it firmly to spring pads formed integral with or supported by the axle. On rear axles the springs are secured to special fittings movable on the axle housing tube in the same manner.

Q. Why are movable spring blocks needed at the rear axle?

A. It is desirable to mount the rear springs on spring blocks which are not rigidly secured to the axle, though kept from end movement by collars, because it is considered good practice to relieve the springs of all driving and braking torque stresses. When

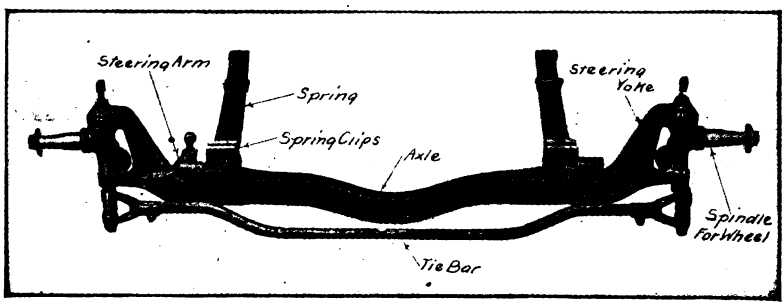


Fig. 198.—View of Front Axle Showing Method of Attaching Semi-Elliptic Spring.

the brakes are employed the tendency of car movement is to turn the axle around in the direction in which the rear wheels are moving. It is desirable to resist this tendency to turn by means of a special restraining member instead of depending upon the springs to do so. Obviously if the spring blocks were securely fastened to the axle housing tube, the tendency of axle rotation would be resisted by the springs which would have to be of heavier construction than if depended only to support the car.

Q. What is driving torque?

A. Driving torque is similar to braking torque and is a tendency the axle has to turn owing to ground resistance to rotation of the driving wheels.

Q. What means are provided to resist these stresses?

A. The rear axle is usually restrained from movement by a special torque tube or rod which runs from the axle to which it is rigidly secured to a suitable restraining member carried by one of the frame cross members. The torque stresses may be resisted by a torque tube as shown at Fig. 199. This member acts as a housing for the drive shaft as well as a torque tube, and owing to its length the turning force present at the differential case will be reduced ap-

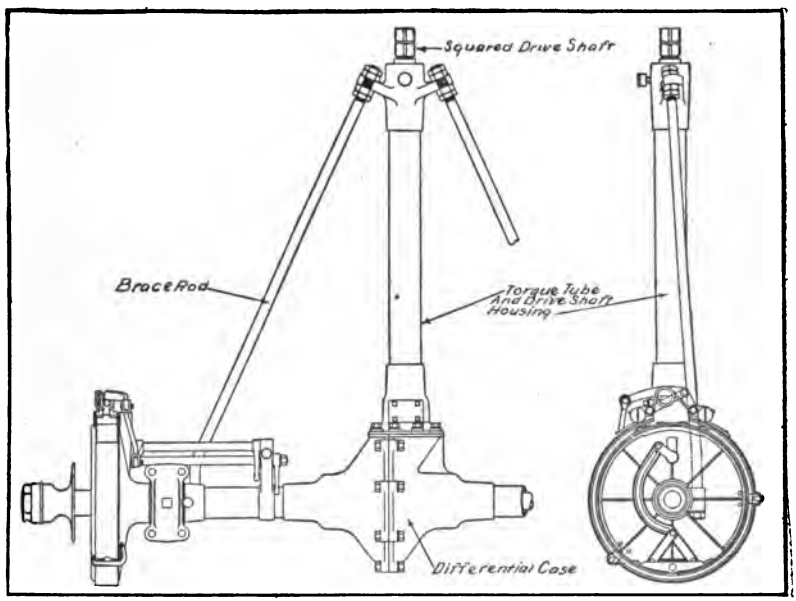


Fig. 199.—Rear Axle Assembly Showing Torque Tube and Brace Rod.

preciably at the upper end. In some driving systems the drive shaft is provided with two universal joints and is not protected by a tube or housing. Axles of the type illustrated at Fig. 200 utilize a separate torque rod which runs parallel to the driving shaft and having its center line on the same plane as that of the drive member. This torque rod is securely attached to the differential housing at the rear end and to a special carrier member adapted to be supported from one of the frame cross braces at its front end.

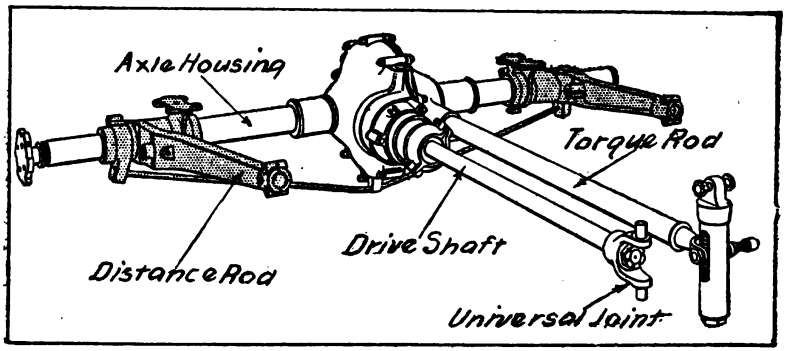


Fig. 200.—Rear Axle Showing Application of Torque Rod and Radius Members to Take Braking and Driving Torque.

Q. What are functions of radius rods?

A. Radius rods or distance members are employed to keep the axle always at the same distance from the frame side, and to act as bracing members to prevent the tendency of one end of the axle to advance more than the other under certain conditions where the driving wheels encounter varying resistances. The brace rods may be of the form shown at Fig. 199 where they are attached to the front end of the torque tube or they may be separate members as shown at Fig. 200 adapted for attachment to the frame at the front end and to the axle at the back.

LESSON TWENTY-THREE

THE STEERING GEAR AND FRONT AXLE

Q. How is the automobile steered?

A. Automobiles may be steered by simple levers or by hand wheels.

Q. What is the simplest method?

A. The simplest forms of steering connection are the direct tiller or lever steering gears actuating the front wheels by direct connecting rods. These lever or tiller steering gears are used at the present time only on electric automobiles, though they were formerly used extensively on all classes of motor vehicles.

Q. How does an automobile front axle differ from that of a horse drawn vehicle?

A. The front axle of a carriage or wagon is a one-piece member, having the wheels revolving on its ends and adapted to swing around a central pivotal point so that the entire axle is moved when it is desired to turn. The axle of an automobile is not movable but the wheels are mounted on independent supporting members so they may be set at an angle when it is desired to direct the automobile in any other than a straight course.

Q. Why is it not advisable to use a movable axle on an automobile?

A. The movable form of axle such as used in carriages and other horse drawn vehicles is well adapted for this purpose because it can be easily swung around by the animals furnishing the motive power. If used on an automobile it would require considerable effort to turn the axle and it would be very difficult to swing the entire axle of a heavily loaded car around if the wheels were in ruts. Another disadvantage of the movable axle would be a loss of stability if attempt was made to turn a corner at even moderate speed.

In a horse drawn vehicle the weight of the animal between the shafts prevents the conveyance from tipping over even if a very short corner is turned, and then again the turns are negotiated so slowly that the tipping effect on the average wagon is practically negligible.

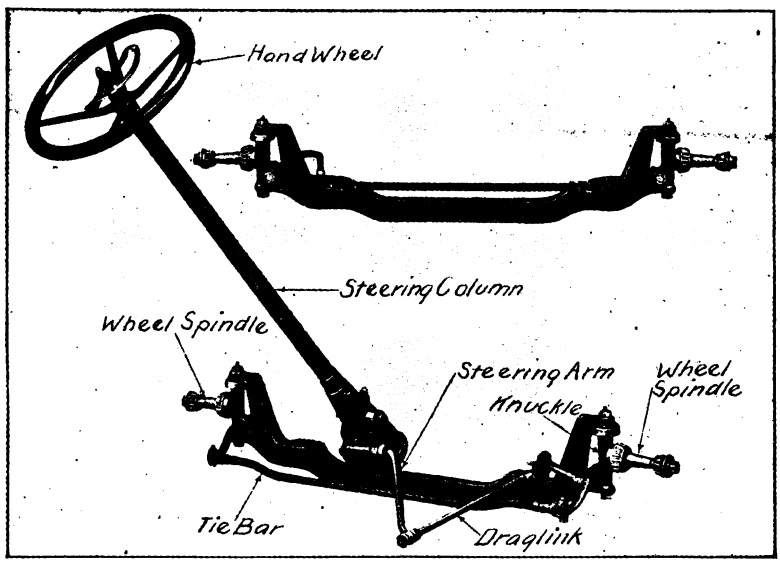


Fig. 201.—Typical Front Axle and Steering Mechanism Showing Method of Moving Wheel Supporting Spindles.

Q. What class of self-propelled vehicle uses a one-piece axle to some extent?

A. One-piece front axles for steering are sometimes applied to steam and gas traction engines, of which the road roller ordinarily used is the most common example. To steer vehicles of this nature the entire front axle is swung around by means of chains attached to the ends of the axle near the wheel hubs and to some form of reduction gear operated by a hand wheel at the other end so that the operator may move the front axle under its heavy load without expenditure of undue energy.

Q. Why can it be used in this application and not on an automobile?

A. As the maximum speed of traction engines is seldom over four miles an hour, the operator has ample time to make a turn and half a dozen or more turns of the handwheel may be used to describe a circle of very large radius. The steering system of the motor car is much more sensitive than that of a traction engine and on account of the higher speeds possible it is imperative that the steering arrangement be such that it will operate immediately and surely. It would not be possible for the average motorist to handle an automobile effectively at even moderate speeds if it was necessary to swing the entire axle as in a road roller or wagon.

Q. How are the wheels moved to steer an automobile?

A. A typical front axle and steering gear arrangement is shown at Fig. 201. The handwheel, which is carried at the end of the steering column, operates the steering arm at the lower end which in turn moves one of the steering knuckles which carries a spindle on which the wheel revolves. The steering spindles at opposite ends of the axle are actuated by a common member so they oscillate in unison, and assume correct angles for diverting the vehicle from a straight course.

Q. What connects the wheels so they will move together?

A. As will be seen by referring to Figs. 201 and 202 the wheel spindles carried in the steering yokes have arms projecting from them at approximately right angles which are joined together by a piece of tubing or rod known as the "tie-bar." Obviously moving one of the wheel spindles must produce a corresponding movement of the other.

Q. What connects the wheels with the steering gear?

A. The steering arm, carried by one of the steering knuckles, is joined to the corresponding member of the steering gear by means of a rod which is called a drag link when it is approximately parallel to the axle as shown at Fig. 202 and sometimes the "fore and aft" rod when installed as shown at Fig. 201 where it is approximately parallel to the frame side member.

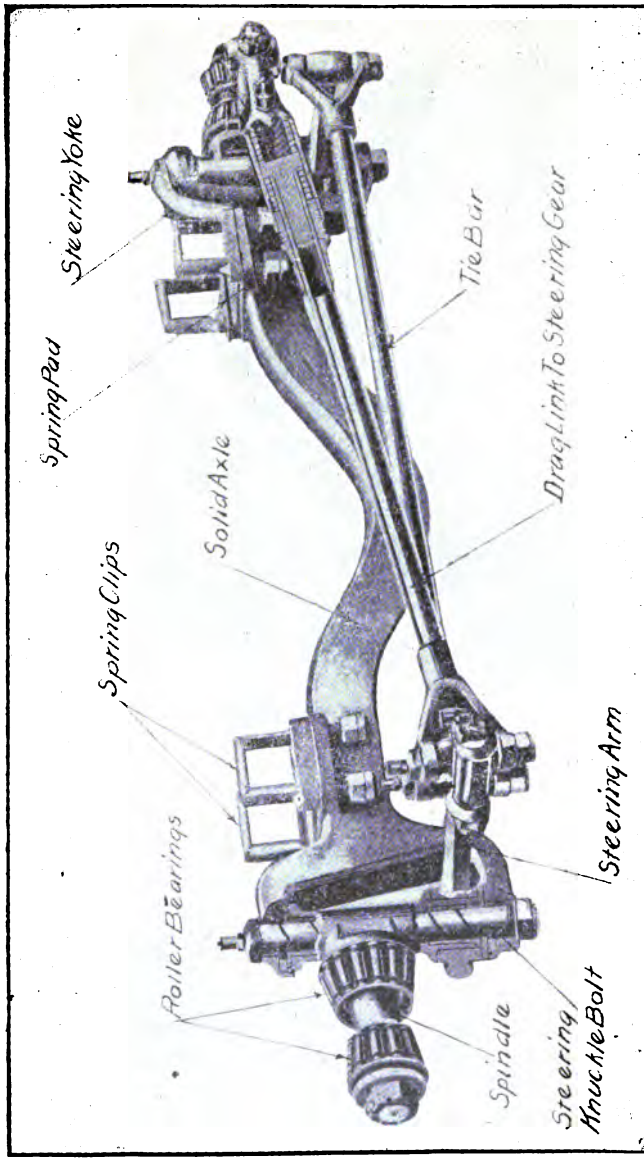


Fig. 202.—Front Axle of Packard Truck Typical of Heavy Vehicle Construction.

Q. What is the main disadvantage of the direct leverage system of steering?

A. The method of moving the front wheels by simple lever connections with a tiller or steering bar operated by the hand offers a disadvantage that it is only suitable for slow moving vehicles on account of the amount of power needed to turn the wheels of even a medium weight conveyance. The direct leverage system of steering is known as a "reversible" steering gear because it is possible to move the hand lever by moving the wheels. This means that every obstacle or inequality of the highway surface that will produce a movement of the steering wheel will also produce a corresponding movement of the hand lever which must be resisted by the person steering.

Q. What is the advantage of gear reduction between hand wheel and steering arm going to the front axle?

A. The use of a hand wheel, instead of a lever, makes for easier handling and the reduction gearing carried at the bottom of the steering post in most cases enables the operator to turn the wheel of even the heaviest automobile without using all his strength. Steering gears may be either of the reversible or irreversible type, the latter being the most common.

Q. Describe simplest form of geared steering arrangement?

A. The simplest form of geared steering arrangement consists of either a spur or bevel pinion carried at the end of the steering post meshing with a suitable spur rack or beveled sector which has two or three times the number of teeth provided on the pinion that actuates it. This means that it will be necessary to turn the handwheel two or three times in order to obtain a full movement of the rack or sector to which the steering arm is attached, which produces the complete movement of the steering wheels from one maximum position to the other.

Q. What are the advantages of spur or bevel rack and pinion steering gears and on what classes of cars are they used?

A. The main advantage of the simple form of steering gear is that they are easily operated and not likely to get out of order. They

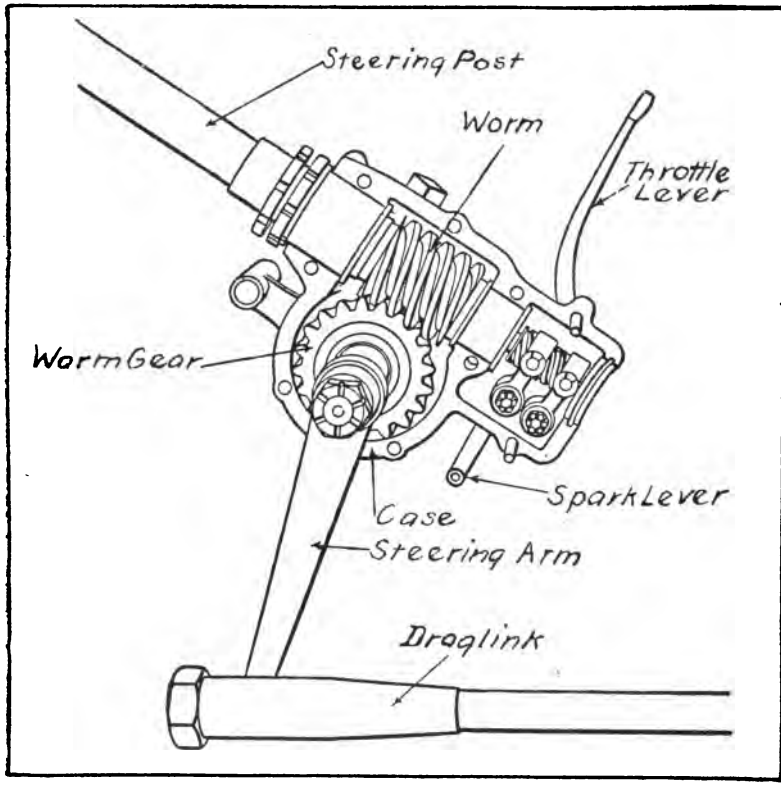


Fig. 203.—Steering Gear of Worm and Wormwheel Type Used on Locomobile Cars.

are not costly to build and usually form the equipment on cheap, light cars where an irreversible steering gear is not absolutely necessary.

Q. What is an irreversible steering gear, and how does it differ from a reversible steering arrangement?

A. The irreversible forms of steering gears are those that utilize reduction gearing that is not capable of being turned except by the handwheel and which is therefore not affected by the action of the road wheels. As previously explained the simpler forms of steering

gear are reversible and movement of the front wheels is communicated directly to the hand lever or wheel, the constant movement of which is apt to tire the operator.

Q. Which is the best type and why?

A. The irreversible forms of steering gear, while slower acting than the simpler reversible type, are the most popular because they are the safest, the most easily handled, and the most powerful form. The wheels of the largest car fitted with an irreversible gear may be turned without difficulty by any person of average strength.

Q. Describe action of worm reduction steering gear.

A. Two forms of worm and worm gear reducing gearing are outlined at Figs. 203 and 204. They are similar in construction, except that one utilizes a complete worm gear to actuate the steering arm while the other employs a worm gear segment. The worm is carried at the lower end of the steering post, being restrained from end movement by ball thrust bearing at either side. It is keyed to the steering column so the worm must be turned with the hand wheel. The worm, as it revolves, rotates the worm gear to which the steering arm is secured and this is oscillated back and forth as the worm is turned. The motion imparted to the steering arm is transferred to the movable wheel spindles on the front axle by means of a drag link. While it is possible to turn the worm gear through the medium of the worm, the pitch of the thread on the latter is such that it is not possible to move the worm and consequently the handwheel used to operate it by moving the steering arm or wheels.

Q. What is a thread and nut steering arrangement?

A. The thread and nut steering arrangement differs from the worm type in that the end of the steering post is threaded with a coarse screw thread and pulls a nut up and down as it is rotated. As the nut is kept from turning it is apparent that it will be moved in one direction or the other and that this movement may be transferred to the steering wheels by means of a simple bell crank lever, the short arm of which is operated by the nut that works up and

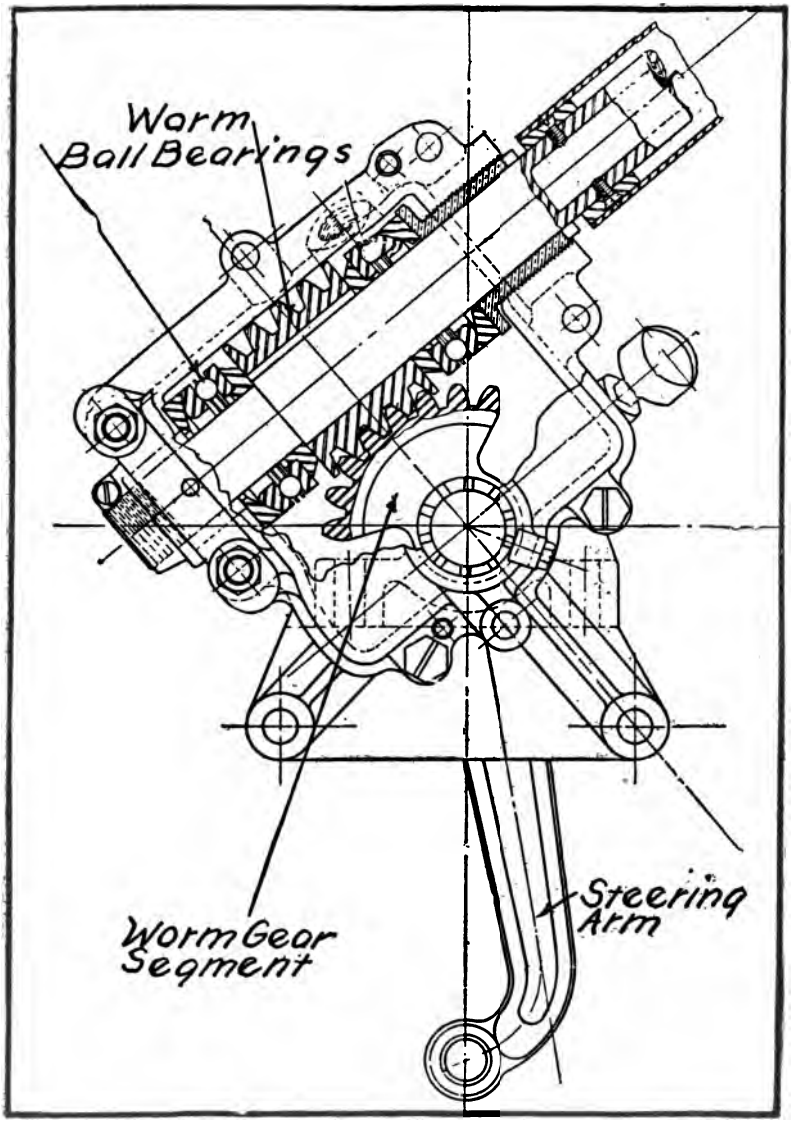


Fig. 204.—Typical Worm and Sector Steering Mechanism.

down on the steering post, while the long arm performs the same function as the steering arm of a worm reduction gear.

Q. Why are the engine control levers usually carried convenient to the steering wheel?

A. The levers used to regulate the time of the ignition and the amount of gas supplied the motor are invariably placed convenient to the steering wheel so the motor speed may be regulated without removing the hand from the wheel rim, except for an instant. In some cases the levers are placed under the steering wheel and are long enough so they may be moved without removing the hand from the wheel rim. In most cars the construction outlined at Fig. 205 is followed. The spark and throttle levers are carried above the steering wheel and operate on a fixed sector member which remains stationary whether the hand lever is turned or not. This means that the levers will always retain the same position unless moved by the operator.

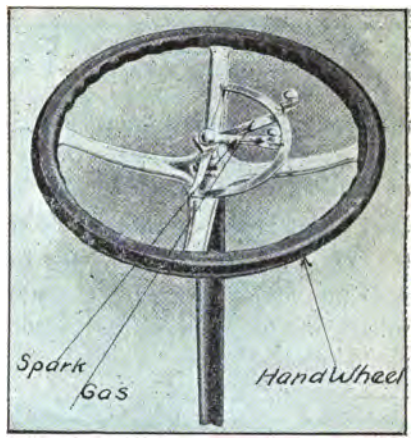


Fig. 205.—Showing Method of Mounting Motor Control Levers at Upper End of Steering Column over Handwheel.

Q. Name two common methods of front axle construction.

A. The two general methods of front axle construction are shown at Fig. 206. The form outlined at *A* is a tubular axle, while that at *B* is a one-piece forging termed the I beam axle.

Q. How are the various parts of a tubular axle assembled to form a unit?

A. The tubular axle is composed of a number of castings or forgings attached to a steel tube. In the construction shown at Fig. 206-A the steering yokes and spring chairs are separately

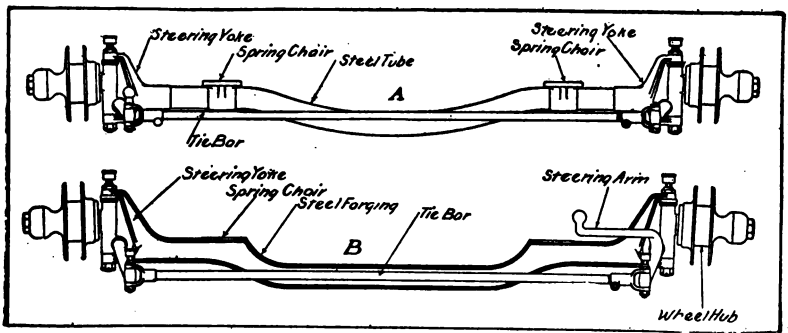


Fig. 206.—Typical Examples of Conventional Front Axle Construction. A—Tubular Axle. B—I Beam Steel Drop Forging.

formed members which are pushed in place on the steel tube forming the axle proper and after being properly located are pinned in place and then brazed to the axle tube.

Q. What is the advantage of the I-beam axle?

A. The I-beam axle is forged in one piece with steering yokes and spring chairs formed integral and there is no possibility of these members becoming loose as sometimes occurs with poorly constructed tubular axles. The I-beam axle is the strongest construction though the tubular form is said to have more flexibility than the rigid forging.

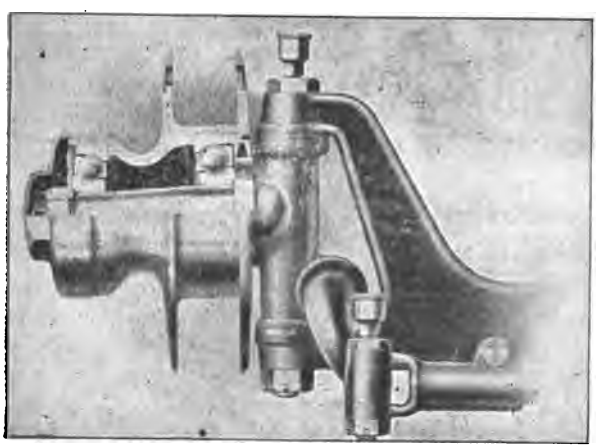


Fig. 207.—Front Hub Mounted on Elliot Type Steering Spindle.

Q. Name two common type of steering knuckles.

A. The two forms of steering knuckles generally used are the Elliot outlined at Fig. 207 and the

Mercedes shown at Fig. 208. In the former, the wheel spindle is attached to a central body member of forged steel that fits in a yoke at the end of the axle and which rotates on a through bolt passing through the axle and wheel spindle boss and forming a bearing for these members as well as holding the assembly together. In the Mercedes type the wheel spindle is attached to a yoke member while the axle is provided with a simple bearing boss, the two parts being held together by a bolt as in the construction previously outlined.

Q. What is the "caster" axle construction and its advantages?

A. Forms of front axles having a peculiar steering spindle construction in which the wheel spindle center line is carried back of

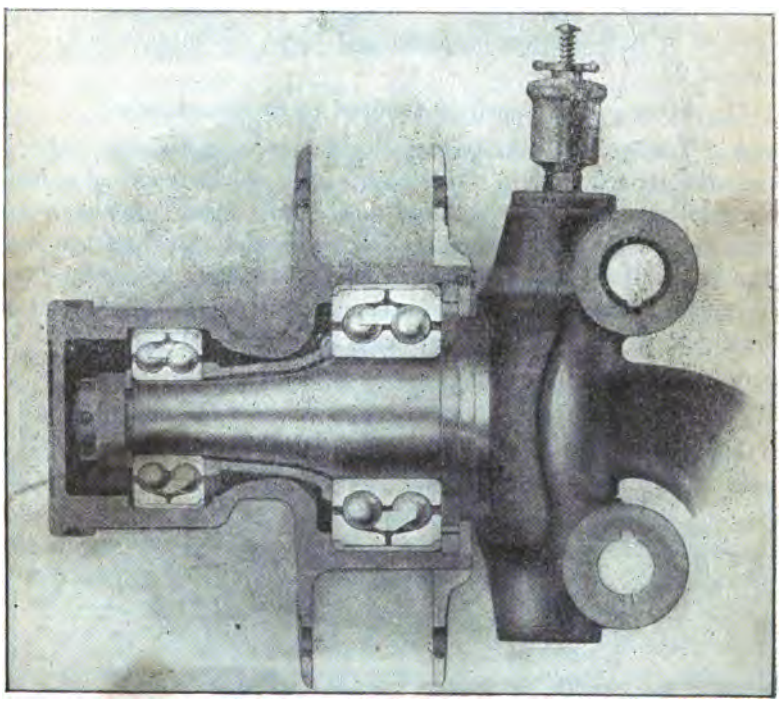


Fig. 208.—Front Hub Mounted on Mercedes Type Steering Spindle.

that of the axle proper are termed "caster axles" because the wheels tend to trail along and run straight even if the tie bar joining the two wheel spindles should break or become loose. It is contended that this form of axle provides greater safety on account of the wheels tending to travel in a straight path automatically. Other claims of easier steering and longer tire life are also advanced by adherents of this method of construction which is not very widely used.

Q. What types of bearings are generally used in front wheels?

A. Front wheels are invariably mounted on anti-friction bearing of the ball or roller form. The wheel hubs outlined at Figs. 207 and 208 are carried on ball bearings while the wheel spindles of the heavy truck axle depicted at Fig. 202 and that of the touring car axle at Fig. 201 are mounted on taper roller bearings. A full discussion of anti-friction bearings and their advantages is given in Lesson 25.

Q. How are the springs secured to the front axle?

A The springs usually rest on pads or spring chairs, either attached to the axle as in the built-up tubular construction or forged integrally in one-piece axles and are kept from moving out of place by means of U shaped spring clips which straddle the springs and pass through the spring pads or chairs where they are held securely by means of locking nuts. The construction of a spring pad and arrangement of spring clips are clearly outlined at Fig. 202.

LESSON TWENTY-FOUR

WHEELS, RIMS AND TIRES

Q. What types of wheels are used for automobiles?

A. Automobile wheels may be divided into two main classifications, those made of wood and the forms composed entirely of metal. Wooden wheels are generally of the artillery type, while metal wheels may be any one of four different forms. The most common metal wheel construction is the wire spoked form similar in appearance to those used on bicycles and motorcycles. Other forms are composed of two metal discs riveted to the hub at the center portion and together at the rim. There is another method of metal wheel construction patterned after the artillery wooden wheel excepting that it is made up of tubing and channel sections brazed together to form the complete assembly. A form of metal wheel that is receiving some application in heavy vehicle service is composed of a large steel casting, having fewer spokes than the usual artillery wheels. These spokes are cast with flanges or ribs which act as a reinforcement and the wheel is a very substantial member.

Q. Describe construction of artillery wheel.

A. The wooden portions of an efficient form of artillery wheel used for pleasure cars are clearly shown at Fig. 209. The spokes, which are made of hickory, are joined together at the central part of the wheel by a series of interlocking mortise and tenon joints which form a very strong assembly and they are inserted into holes in a wooden felloe at their outer ends. The complete artillery wheel with metal hub and rim in place is shown at Fig. 210, while the two forms outlined at Fig. 211 show clearly the method of holding the lower end of the spoke securely between the main hub casting and the metal flange which acts as a clamping member. The main casting serves as a housing for the bearings on which the wheel revolves.

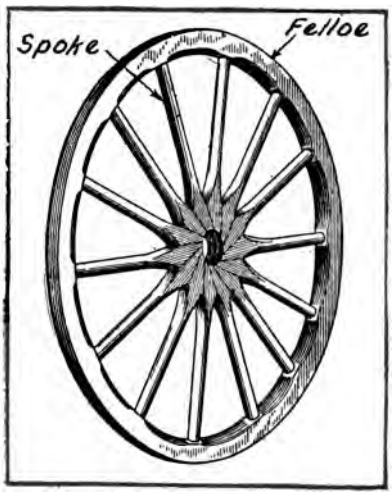


Fig. 209.—Wooden Parts of Typical Artillery Wheel

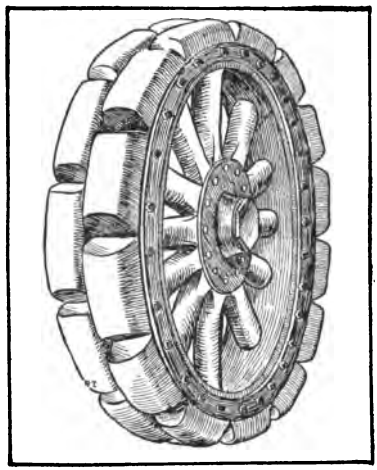


Fig. 210.—Heavy Artillery Wheel for Motor Trucks.

The wheel shown at *A*, Fig. 211, is a lighter form than that outlined at *B* and is intended for application on the front axle of a motor truck. The heavier and stronger wheel with sprocket and brake drum attached is one of the traction members that revolve on the rear axle. The rubber tires with which these wheels are provided are not shown in this view but the appearance of a complete wheel with sectional block tires and retaining flanges in place is clearly depicted at Fig. 210.

Q. Describe a typical cast-steel wheel for motor trucks.

A. Heavy cast-steel wheels intended for use on a large motor truck of German design are shown at Fig. 210-a. That at *A* is a front wheel and is fitted with a single tire. That at *B* is a rear wheel with rim of sufficient width to take two solid rubber tires side by side. The wheel construction consists of a steel casting having cored spokes and rim to give it lightness, provided with a plain bearing hub. The construction of the front and rear wheels is similar except that the hollow rim and spokes of the latter are of larger size and the spokes are provided with bosses through which the

bolts holding the driving sprocket and brake drum in place are secured. The use of plain bearings is not general on American motor trucks on account of the friction present when the wheels are heavily loaded. Plain bearings are suitable only where truck speeds are very low and the motor has a margin of power over the actual requirements.

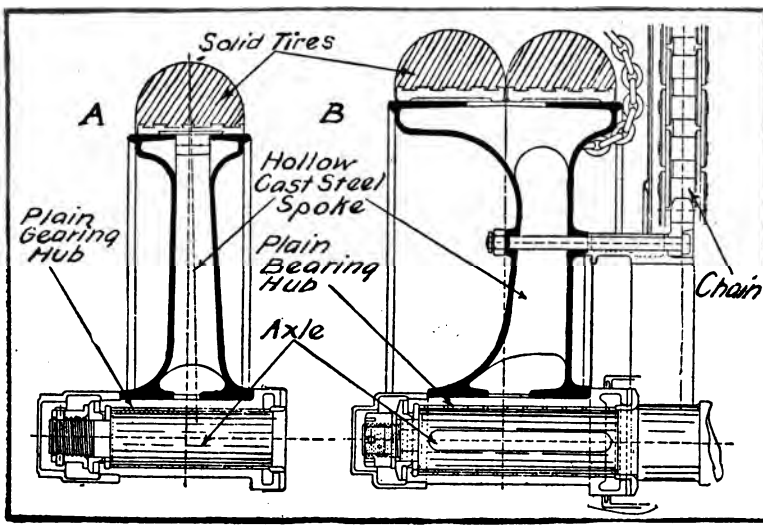


Fig. 210A.—Motor Truck Wheels of German Design Made by Steel Casting Process.

Q. Outline construction of wire spoke wheels and state their advantages.

A. A tangent spoke wire wheel adapted for automobile use complete with tire is shown at Fig. 212, while the various methods of wire wheel construction in vogue are outlined at Figs. 213, 214, and 215. Wire wheels may be of either the double or triple spoke construction as indicated at *A*, Fig. 213. The double spoke type follows lines that have been established as standard in bicycle and motorcycle construction and differs but slightly from the wheels used on the lighter vehicles except in the matter of structural strength of the components. The triple spoke construction has been devel-

oped especially with the requirements of the heavier forms of self-propelled vehicles in mind and is stronger than the form having a lesser number of spokes.

The spokes are similar in construction to those used in bicycle wheels but are much stronger and made of higher grade material

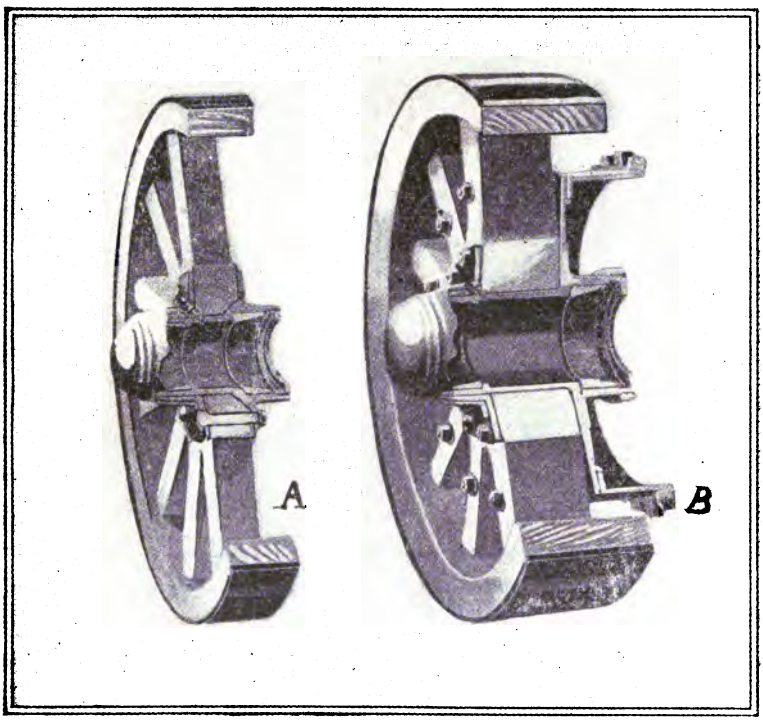


Fig. 211.—Part Sectional View of Heavy Artillery Wheels Used on Packard Trucks.

on account of the severe duties they perform. The spoke is provided at the lower end with a button head to keep it from pulling through the hole in the hub when it is tightened by the threaded nipple at the upper end passing through and having a head which bears against the rim. After the spokes of a wire wheel are in place all the nipples are screwed up so that the tension on practically all

the spokes is as nearly the same as it is possible to obtain and have the wheel run true. The method by which the upper end of the spoke is attached to the rim is clearly outlined at Fig. 213-B.

The construction depicted at Fig. 214 is the Rudge-Whitworth wire wheel fitted with the Houk quick detachable rim. The wheel is of English design and is widely used abroad. It is of the triple spoke pattern and is made so it can be removed easily from the inner hub casting in which the bearings are carried. The hub shell to which the spokes are fastened is held in place by means of a substantial locking nut *F* which keeps the serrations in the hub members firmly together to insure that the two parts *B* and *E* will turn as a unit when the lock nut *F* is tightened. The wheels shown at Fig. 215 are an American pattern known as the McCue, that at *A* being a front wheel while the form outlined at *B* is used on a live axle and serves as a traction member.

Fig. 212.—Typical Wire Spoke Wheel.

It is claimed that with wire wheels considerably more elasticity is present than in wooden members and that this type of wheel is much easier on tires. Experiments conducted during the past two or three years have served to establish the belief in some quarters that wire wheels double the life of tires as compared to wooden wheels. The main reason advanced is that wire wheels are extremely light at their peripheries and the reduction of weight at this point overcomes the flywheel effect and heavier blows of the wooden wheel rim when it strikes an obstruction in the roadway. The difference between the effect of shock on the tires of a wooden wheel with a heavy demountable rim at its periphery and the wire wheel with its light

single rim is equal to the difference between a blow struck with a light hammer and one struck with a hammer weighing six or eight pounds. Obviously, as the wheel revolves the force of the tire striking the surface of the road is almost the same as though a blow were being struck against the tire

With the wire wheel the weight is suspended from seventy common points. It is never entirely supported on one spoke in compression as is the case with a wood wheel. When an obstruction is met it is like striking a punching bag between ropes as the shock

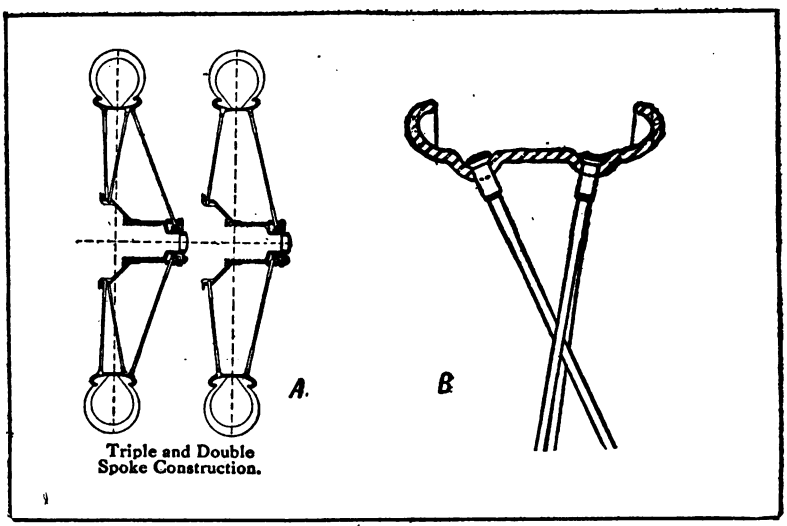


Fig. 213.—Outlining Structural Details of Wire Wheels. A—Arrangement of Spokes. B—How Spokes are Secured to Rim.

is absorbed by the flexible steel members joining the wheel rim to the hub. With wooden spokes a portion of the shock is absorbed by the wood but a large part of it is transmitted directly to the wheel hub.

Another quality of equal importance is the ability of the wire wheel with the spokes laced tangent to absorb the shock of starting or sudden application of power in the plane in which the wheel rotates. This quality is absent in wood wheel construction.

It is a well known fact that the friction between tire and road generated in driving a car at even a reasonable speed results in quick and excessive heating of the tire structure. In the wood wheel, which serves in a sense as insulation, there is a very slight ability to quickly dissipate heat. Wire wheels requiring only a thin metallic rim, the spokes serving in a sense as cooling flanges, will dissipate this heat almost as quickly as it is generated. This results in keeping the tire at almost normal temperature even in very warm weather.

The wire wheel properly constructed can be manufactured and kept so nearly true, both laterally and circumferentially, that it practically eliminates all wear other than that resulting from the friction of a perfectly true revolving wheel.

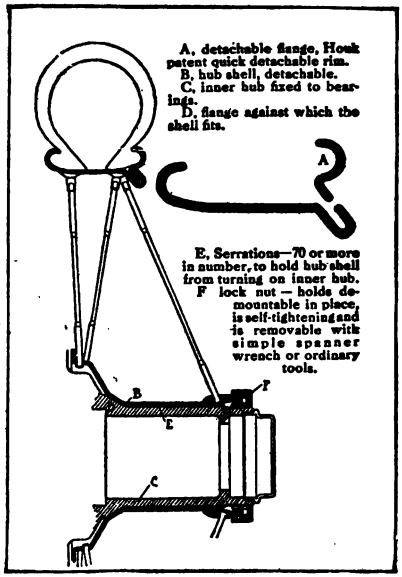

A, detachable flange, Hook patent quick detachable rim.
B, hub shell, detachable.
C, inner hub fixed to bearings.
D, flange against which the shell fits.
A
E, Serrations—70 or more in number, to hold hub shell from turning on inner hub.
F lock nut — holds demountable in place, is self-tightening and is removable with simple spanner wrench or ordinary tools.
B
F
E
C

Fig. 214.—Construction of Rudge-Whitworth Detachable Wire Wheel.

Q. What are detachable wheels and where are they used?

A. Detachable wheels may be either of the wire wheel pattern or of the artillery construction. In all forms of detachable wheels two hubs are necessary, an inner member which is in permanent assembly with the axle and a removable outer member to which the spokes and rims are attached. In the Rudge-Whitworth construction shown at Fig. 214 the steel shell to which the spokes are laced is readily removable from the inner member or hub casting proper. The object of this construction is to permit the motorist to carry a spare wheel with a fully inflated tire so that in event of puncture or blowout it is possible to remove the entire detachable wheel assembly affected and replace it with the spare member carrying the

fully inflated tire which has been provided for replacement purposes. All detachable wheels are constructed so that they may be readily removed from the inner hub member and the entire wheel assembly may be replaced much easier and quicker than replacing the ordinary form of tire.

The wheel shown at Fig. 215 is a quick detachable form normally held in place on the tapering hub shell member by a threaded re-

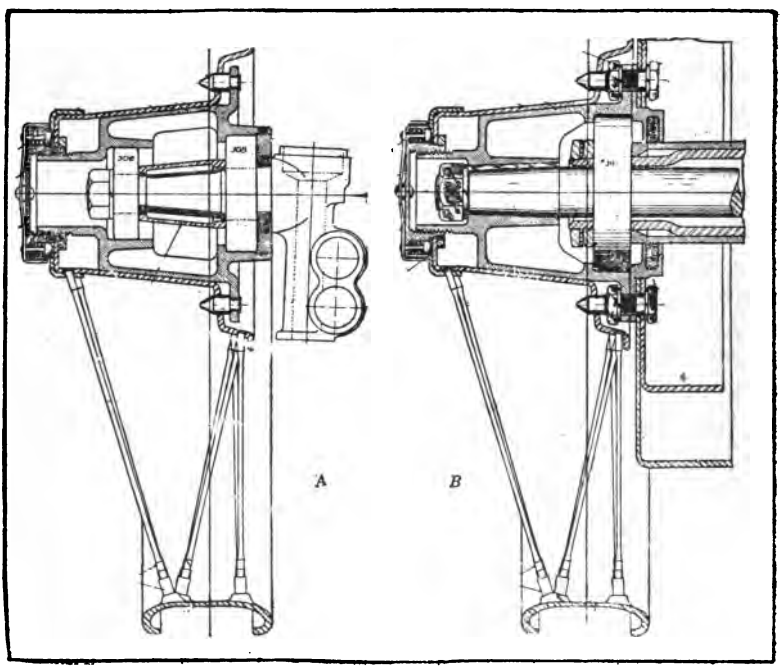


Fig. 215.—Typical American Wire Wheels of McCue Design.

tention nut and which is driven by means of a series of pointed driving pins riveted to a flange on the inner hub and passing through suitable openings in the outer hub shell. The construction of front and rear wheels is practically the same, except that the inner hub of the former is intended to revolve on the steering spindle while

that of the latter is keyed to the driving axle and revolves on a bearing carried by the driving axle housing.

The Rambler detachable wheel, which is an artillery type, is shown at Fig. 216. To remove this member it is necessary to unscrew six nuts which serve to hold the wheel against the flange on the inner hub. The conventional method of carrying a spare wheel is outlined at Fig. 217.

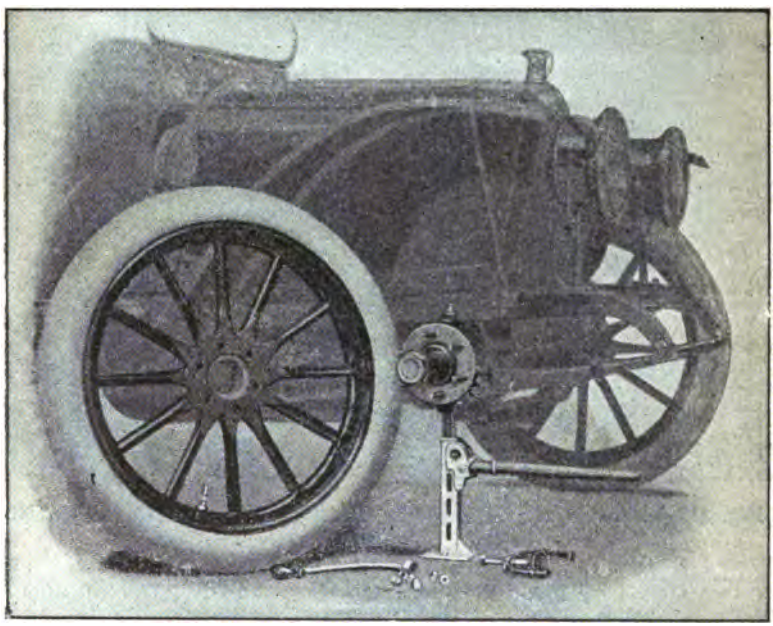


Fig. 216.—The Rambler Detachable Artillery Wheel.

Q. Are spring wheels practical?

A. Various forms of wheels having resilient or spring like members joining the wheel rim and hub have been devised with the object of doing away with the pneumatic or inflated tire. None of these have proven practical on account of their greater weight than either wire or wooden spoke forms and also because they do not prove resilient enough except at very low speeds to replace the

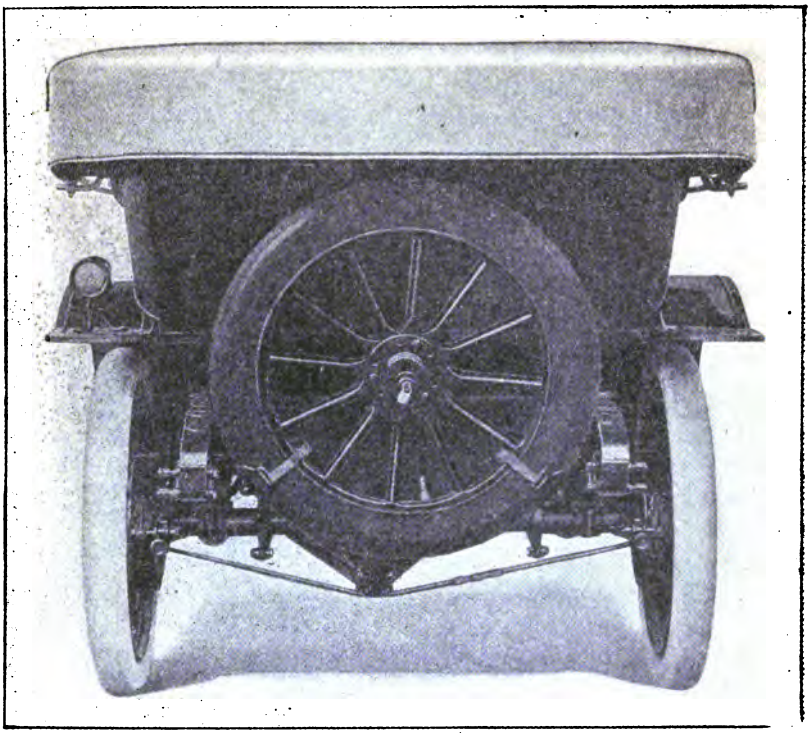


Fig. 217.—How Detachable Spare Wheel May Be Carried When Not in Use.

rubber tire. In most of these constructions a large number of springs or similar yielding members are employed, and as there is a multitude of joints to wear, the wheels are very noisy in action. In addition to the features enumerated the construction of most spring wheels is costly and complicated and often the failure of one or two of the resilient members interposed between hub and rim will mean a loss of integrity of the entire assembly.

Q. What are the functions of the wheel rim?

A. The main function of the wheel rim in automobile wheels is to support and retain the tire with which the wheel is provided and which is in contact with the roadway.

Q. How is the rim secured to the wheel?

A. The method of securing the rim to the wheel depends entirely upon the type of wheel employed. In artillery wheels the rim is attached to the wooden felloe by being shrunk on just as a carriage tire is on a carriage wheel and it is kept from moving by means of bolts passing through rim and felloe. In a wire wheel the rim is secured to the hub by means of the spokes which complete the wheel assembly. In some disc wheels and those made by the process of pouring molten metal in a mould the rim is an integral part of the wheel.

Q. What factor determines rim design?

A. The design of wheel rims depends entirely upon the type of tire to be used and this in turn is dependent upon the character of work the vehicle is expected to perform.

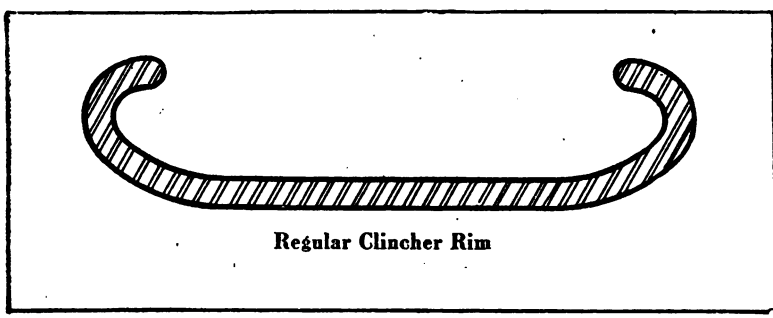


Fig. 218.—Section of Regular Pattern Clincher Rim.

Q. What is the clincher rim?

A. The clincher rim is the simplest form used on pleasure automobile wheels and is shown at Fig. 218. It consists of a strip of steel rolled to the section shown and formed into a continuous ring which encircles the wheel felloe or to which the spokes of a wire wheel are attached by threaded nipples, as previously described. A special form of tire, known as a clincher, having two beads or flaps that fit under the inwardly turned flanges of the rim with considerable pressure when the tire is fully inflated, must be used

with this type of rim. The clincher is a very popular rim on light cars and motorcycles, but owing to the trouble that obtains in removing large clincher tires it is being replaced with the various quick detachable forms on the heavier cars.

Q. What is a quick detachable rim?

A. In a clincher rim it is necessary to pry the casing of the tire over the flanges in order to remove it from the rim. Two forms of quick detachable rims which have received general application are

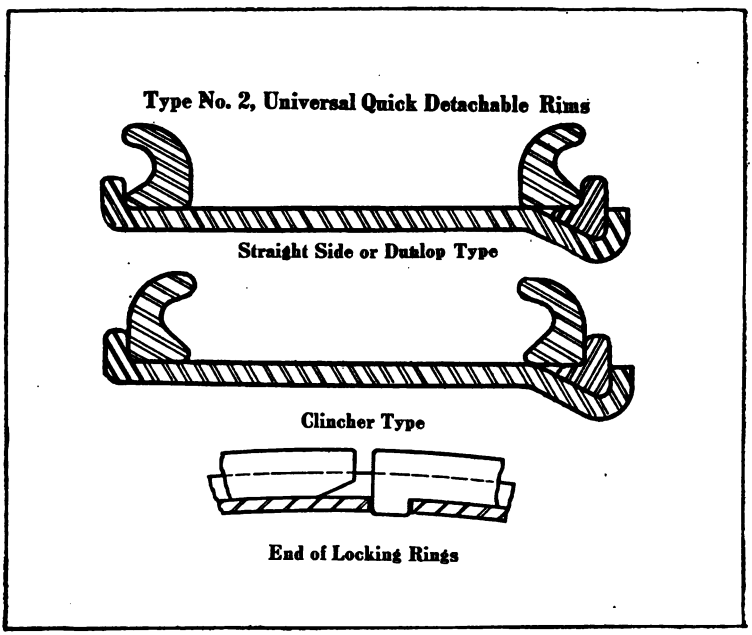


Fig. 219.—Typical Quick Detachable Rim Suited for Either Dunlop Straight Side or Regular Clincher Casing.

shown at Fig. 219. A member of this pattern consists of a main rim that encircles the wheel felloe and two removable tire retaining rings and a locking member. The universal quick detachable rim illustrated is capable of holding either a straight side tire or one provided with clincher beads. In this type, when a tire is deflated, it is merely necessary to remove the locking ring from the rim and

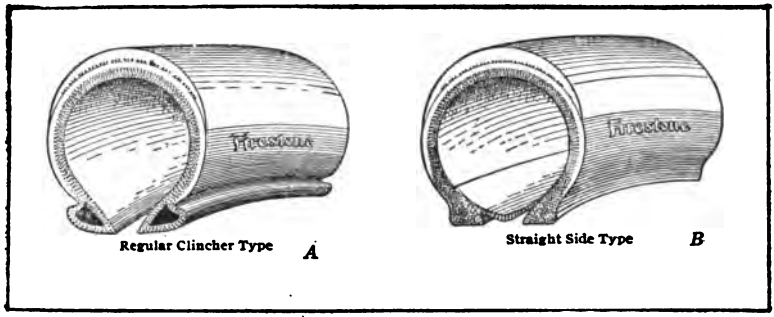


Fig. 219A.—Methods of Attaching Outer Casings. A—Clincher System. B—Dunlop Design.

then the outside retaining ring can be slipped off of the wheel rim and the tire casing pulled off in just the same manner as a loose belt off a pulley. As there is no necessity for prying the tire off of the rim the larger sizes are much more easily handled than are large clincher tires.

Q. What are demountable rims?

A. A demountable rim is any form which may be easily removed from the wheel if desired by merely removing the retaining nuts. This method of construction makes it possible to carry spare rims with fully inflated tires in place so that minimum time is required to replace a defective tire. A typical demountable rim partially removed from the wheel is shown at Fig. 220.

Q. What are "bolted-on" rims?

A. "Bolted-on" rims are the forms in which the tire is held in place on the wheel between two flanges which are retained by bolts passing through the flanges and the wheel felloe. This form of rim is largely used for solid tires.

Q. Describe construction of typical demountable rims.

A. A typical demountable rim is outlined at Fig. 221. As will be seen it consists of a form of quick detachable rim adapted to be locked in place on the rim carried by the wheel felloe by means of a double locking wedge forced under the tire carrying rim by a series of locking bolts. The usual number of locking bolts is six

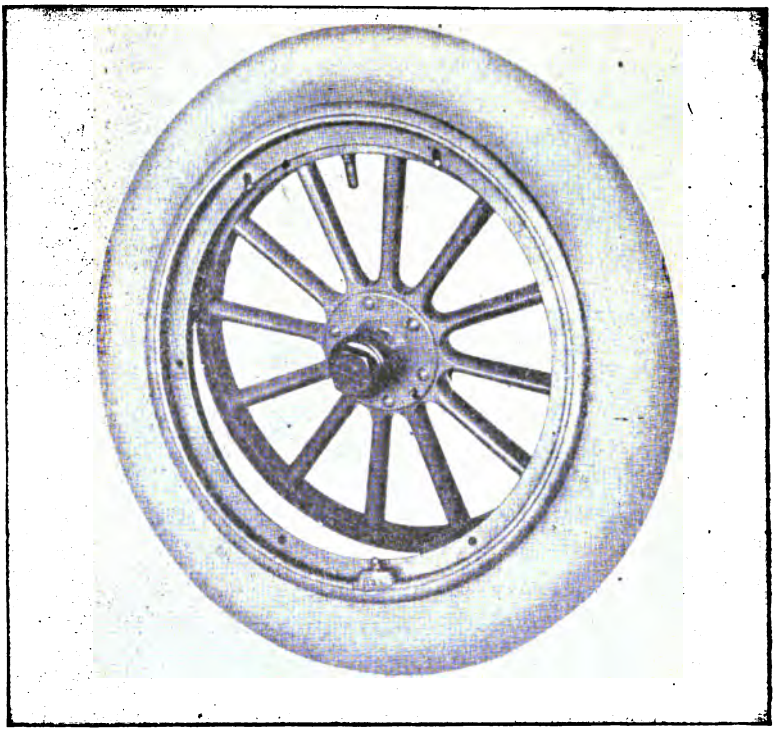


Fig. 220.—Example of Demountable Rim, Showing Method of Removal From Wheel.

on a twelve spoked wheel, though on some forms of cars capable of high speeds, it is thought desirable to provide one bolt between each pair of spokes instead of between alternate pairs.

Q. What are solid tires and what class of vehicles are they used on?

A. Various forms of solid rubber tires are shown at Fig. 222. These consist of a special rubber and fabric composition moulded together under high pressure and vulcanized until a solid ring of resilient material is obtained. Solid tires are generally used on heavy motor vehicles intended for commercial purposes. As a rule these

conveyances travel at low speeds and the solid rubber tire provides sufficient resiliency to eliminate a large part of the road shock and protect the mechanism.

Q. Have steel tires ever been used on motor vehicles?

A. Steel tires have been tried on heavy motor vehicles but are not suitable on account of their lack of resiliency and poor traction. They are only applied in cases where extremely heavy loads that would be greater than the capacity of rubber tires are carried and on extremely slow speed conveyances intended for use on soft roads or in fields, as on gas tractors, where studs or cleats may be placed on the rims to increase traction.

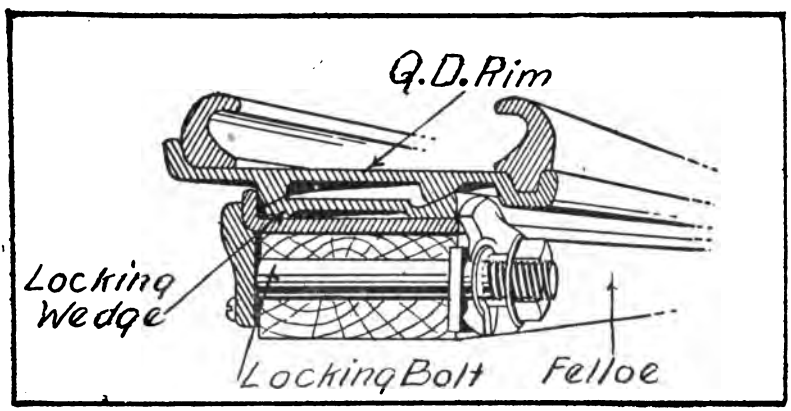


Fig. 221.—Sectional View of Demountable Quick Detachable Rim.

Q. What are the advantages of dual tires?

A. On heavy motor vehicles where the types of solid tires outlined at Fig. 222 would not have sufficient capacity it is customary to mount two of these tires on a common rim, as outlined at Fig. 223. This provides more capacity than a narrower tire used singly and at the same time has important advantages over using a single wide tire adapted to fit the wheel rim. The wide tires are hard to make and unwieldy to handle. The use of two tires side by side not only provides greater resiliency and superior traction but also tends to reduce side slip or skidding. In event of damage to one section

or side of the tire it is necessary to replace only the tire affected and in an emergency should one tire be severely cut it will be possible to run on its mate until the garage is reached.

Q. What are the features of sectional or block tires?

A. When a continuous solid tire is used, the weight of the vehicle tends to flatten it out as indicated at Fig. 224 and this is called a "traction wave" which assists to produce disintegration of the

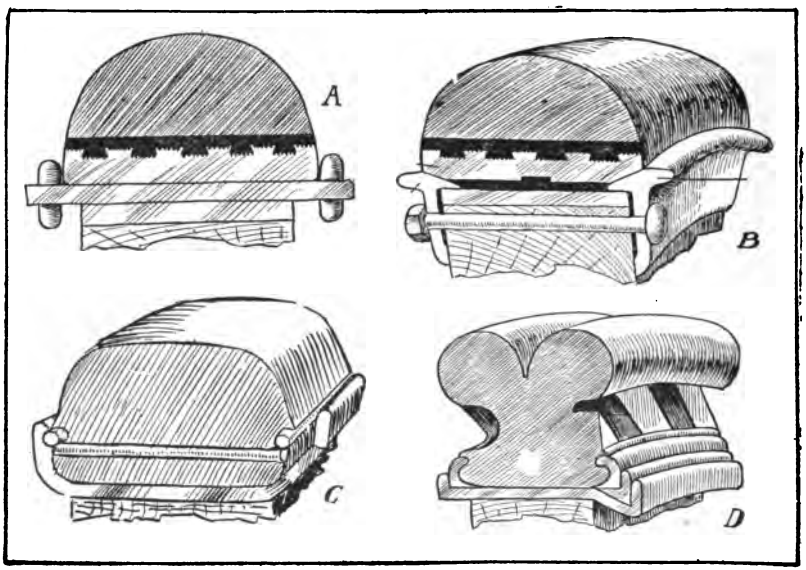


Fig. 222.—Sectional Views of Solid Rubber Tires Showing Methods of Attaching to Wheel Rim.

tire as it is continually stressed at the point of contact between the wheel and the ground. In the upper view *A* indicates the traction wave, while *B* shows the point at the base of the tire where the tread and body portion tend to separate. By the use of sectional or notched tires, the destructive traction wave is eliminated because when the blocks flatten the wave passes off into the space between two blocks as indicated at *A* in the lower view. In the construction shown the base, however, is continuous to insure absorption of vi-

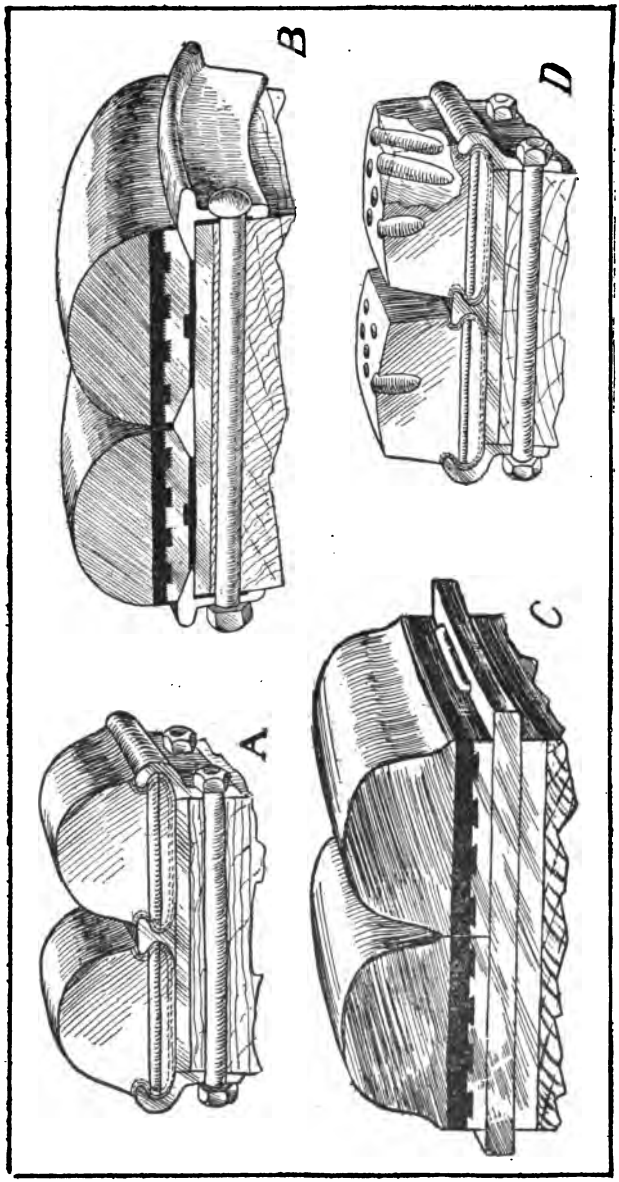


Fig. 223.—Construction of Typical Dual Motor Truck Tires Outlined.

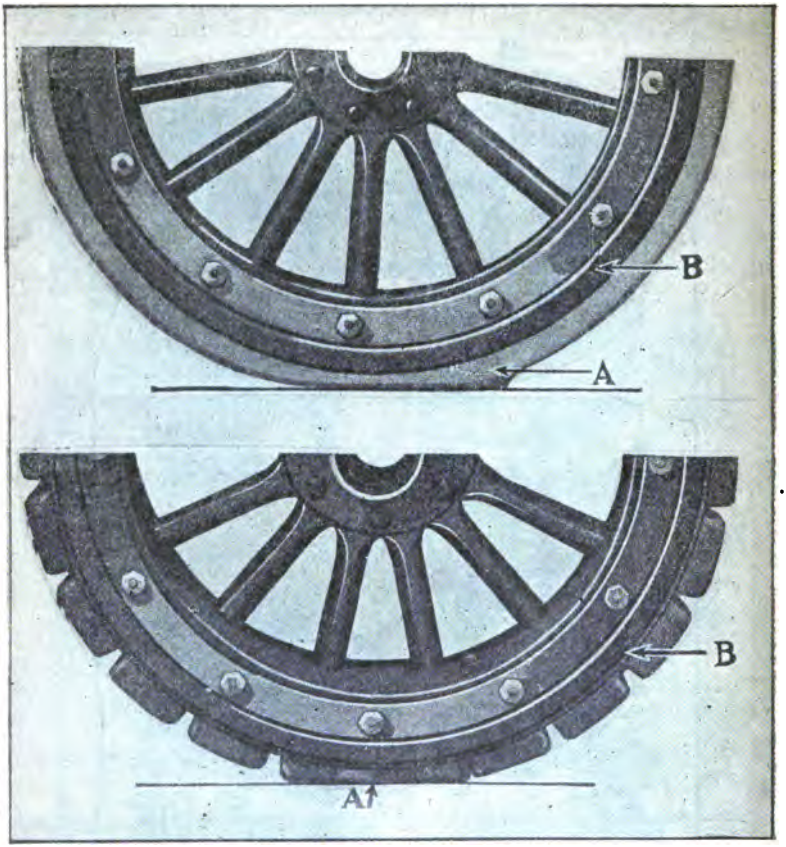


Fig. 224.—Showing One Advantage of Sectional Block Tire Design Over Continuous Tread Type.

bration in every direction and prevent concentration of the load on one portion of the tire as would be the case if separate blocks were used. The separate block construction, however, has an important advantage in that it permits of replacing one or more defective blocks without necessitating the renewal of those which have not been so severely punished. It is claimed that very often a one-piece tire will be so badly cut or bruised at one point that it

will have to be removed for repairs even though the rest of the tread is not affected. In a sectional or block tire only the injured portion would have to be replaced, which means more economical maintenance because of easier installation.

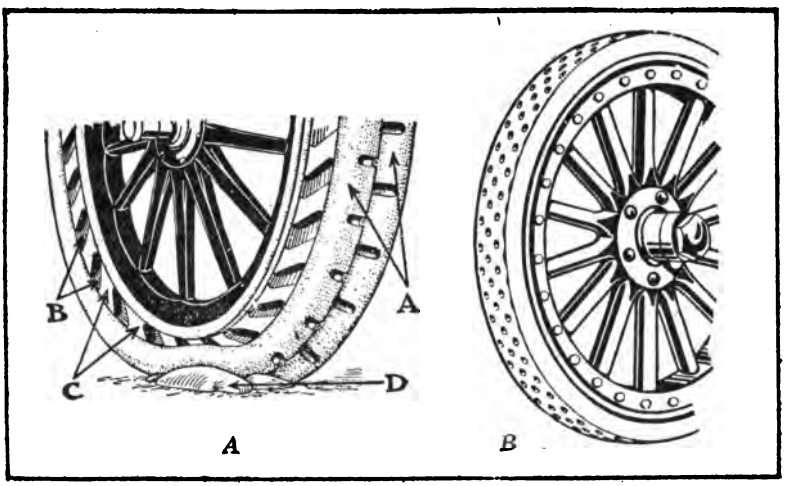


Fig. 225.—Leading Forms of Cushion Tires. A—Motz. B—Swinehart.

Q. What other materials besides steel and rubber have been used for motor vehicle tires?

A. Experimental tires have been made composed of wood with the fibers or grain running parallel to the spokes and have given satisfactory service in certain applications. Various textile fabrics have also been tightly compressed together to form a practically solid mass and have been tested and found satisfactory. It is claimed that wood or textile fabrics offer a greater degree of resiliency than a steel tire and have a traction effort or friction grip on the ground equal to a rubber tire operating under favorable conditions. It is claimed, also, that these provide superior traction to rubber in muddy roads or on wet asphalt.

Q. What is a cushion tire and on what vehicles are they commonly used?

A. Cushion tires are a composite form intended to provide more resiliency than solid tires and at the same time eliminate the troubles incidental to the use of inflated members. Two methods of obtaining a cushion effect are outlined at Fig. 225. The tire shown at *A* is a twin tread form composed of very resilient rubber compound, provided with a series of notches cut around the tread as indicated at *A* and attached to the rim by means of bridges of compound separated by air spaces *B*. When a tire of this construction passes over an obstruction *B*, it can deform considerably on account of derangement of tread and supporting members and the wheel does not ride over the obstacle, as would be the case if the tire did not

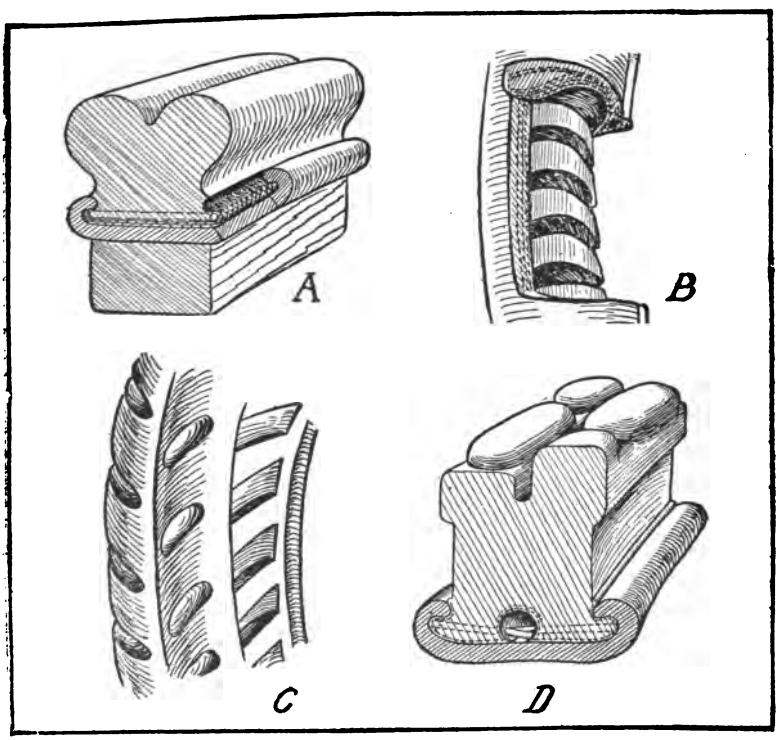


Fig. 226.—Typical Cushion Tires Showing How a Certain Degree of Resiliency May Be Obtained Without Air.

give to any extent. In the tire shown at *B*, the resiliency is obtained by breaking up the mass of rubber by a large number of holes which permit of greater flexibility. Cushion tires are generally used on light delivery wagons or electric automobiles. They are suitable only for slow or moderate speed vehicles, as they are not sufficiently resilient to cushion the mechansim from the shocks incidental to high speeds.

Q. What is an "airless" tire?

A. The term "airless" tire is synonymous with cushion tire and includes all forms in which resiliency is obtained by peculiar tread formation or air substitute filling instead of by compressed air. Various forms of airless tires are shown at Fig. 226. That at *A* is the simple cushion form of the twin tread type moulded of resilient rubber compound. The form at *B* is known as the Dayton "airless" tire and resembles the conventional form of clincher casing, the exception being that the load is supported by means of arches of very resilient rubber separated by air spaces which permit of distortion of the load carrying blocks. It is claimed that this construction offers important advantages inasmuch as the tread portion can be made of a tough, wear resisting compound whereas the more resilient load carrying blocks which are not subjected to ground friction can be made of softer and more easily deformed rubber composition. In both the forms shown at *C* and *D*, the peculiar tread formation is depended on for resiliency.

Q. Why are pneumatic tires necessary on most automobiles?

A. Pneumatic or air filled tires are used on most automobiles because it has been demonstrated that the air cushion is the best shock absorbing medium known and the only one that is capable of taking the vibrations following in rapid sequence when a car is driven at speeds over fifteen miles per hour. Not only is it the easiest riding form but it insures longer life to the mechanism and also increased traction effect on practically all classes of road surfaces.

Q. What is the usual construction of a pneumatic tire?

A. Two forms of pneumatic tires are outlined at Figs. 227 and 228. The types that are generally used on automobiles are composed

of two main portions, an outer casing, sometimes called the shoe, which is subjected to the road wear, adapted for fastening to the rim either by means of beads that fit in rim channels as shown at Fig. 227 or that is clamped to a rim between retaining rings as shown at Fig. 228. The shock absorbing portion of the tire is an inner tube of almost pure rubber inflated with air but protected from contact with the road by the more resistant outer casing.

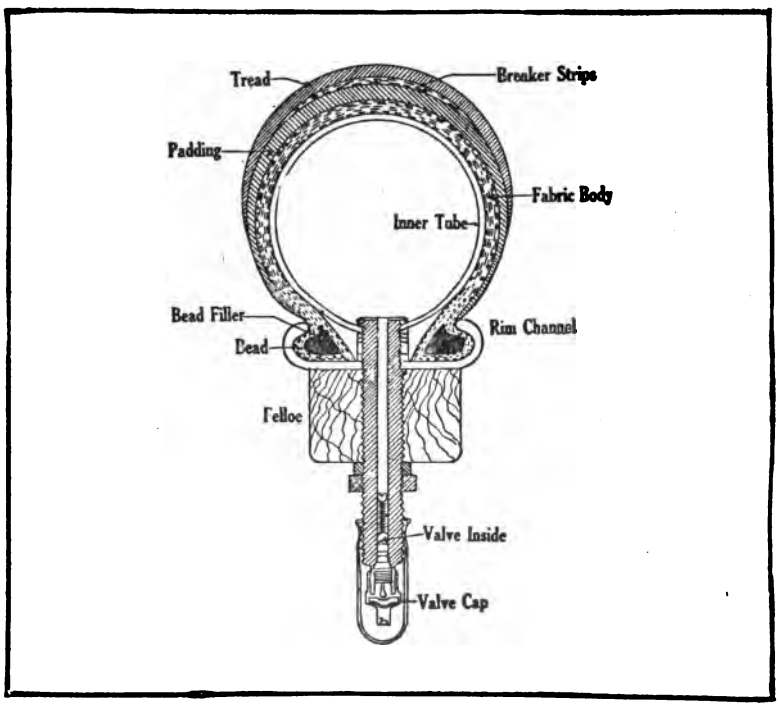


Fig. 227.—Construction of Clincher Tire of Double Tube Form.

Q. What is the outer casing composed of?

A. The outer casing of most automobile tires is composed of a fabric body, which is made of layers of canvas impregnated with rubber and covered by a padding of very resilient rubber composition. On top of this padding a number of fabric strips are placed,

these being called "breaker" strips, and these in turn are covered by another layer of tough rubber compound called the "tread." The fabric layers comprising the main carcass are brought around a hard rubber filler member at the base of the tire to form the beads

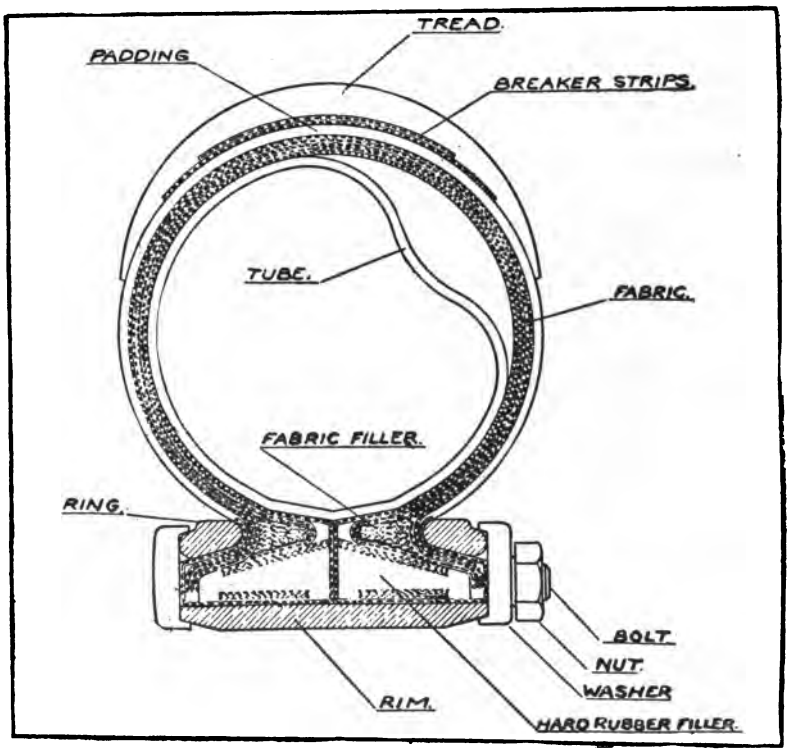


Fig. 228.—Showing Construction of Fisk Bolted-On Tire.

to fit in the clincher rim. While the outer casing is built up of these various layers of rubber compound and cotton fabric it is subjected to a process of vulcanization or heat treatment which results in firmly welding or cementing the various cloth and rubber layers into one unit structure.

Q. What are the functions of the tread, breaker strips, carcass, and bead of casing?

A. The tread is made of the compound of rubber and various mineral elements designed to increase its toughness and resistance to depreciation resulting from abrasion of the road surfaces. The breaker strips interposed between the tread and the padding or cushion are depended on to prevent sharp objects from penetrating through the main fabric carcass. The breaker strips usually turn aside many of the puncturing objects that penetrate the outer tread.

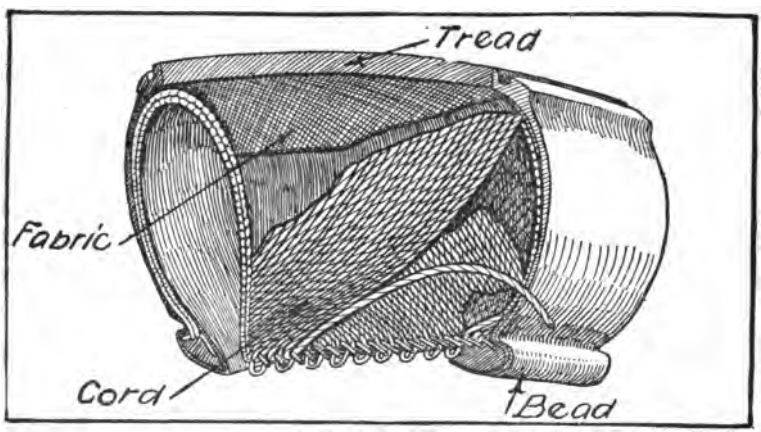


Fig. 229.—Construction of Palmer Cord Tire Outlined.

The padding beneath the breaker strips is a cushion of very resilient rubber compound while the carcass really forms the main body and inner tube retaining portion of the tire. The bead on the bottom of the casing, which is composed of a hard rubber filler piece around which a number of plies of fabric are wrapped, is depended on to hold the tire in place in wheel rim.

Q. Are outer casings always composed of fabric?

A. Outer casings are not always built up exclusively of fabric and rubber materials, sometimes the main body of the tire is formed by winding cords around the layer of fabric that serves as a basis

upon which the entire tire is built. A partial section view of a tire of this nature is shown at Fig. 229 and it will be evident that the layers of cord are separated from each other by plies of friction fabric. The tread and padding as well as breaker strips are put on the cord carcass in just the same manner as they are applied to a fabric structure. Tires of this construction are much more resilient and are capable of giving considerably more mileage than the stiffer form comprised entirely of fabric. For this reason they are sometimes used on electric automobiles, but as they are difficult to repair and are more apt to become punctured than the stronger and less resilient members they have received but limited application.

Q. How do outer casings of various makes differ in construction?

A. The general design of practically all outer casings is the same though there are minor differences of structural detail. For example, some makers will use finer fabric and more layers than others, and each manufacturer has his own specific formulæ for compounding rubber to the best advantage. Some tires are made with a straight side at the lower end instead of the clincher bead, whereas others are adapted to be secured to the rim by means of bolts. There are also differences in the thickness of the tread and of the padding and breaker strips. Some makers build their tires by what is known as the moulded process while others favor the wrapped tread construction. In the first mentioned method, after the various layers of material of which the tire is composed are assembled together on the core, the assembled tire is clamped tightly in a mould and vulcanized. In the wrapped tread construction, instead of curing the rubber in a mould the finished tire assembly is wound tightly with narrow strips of webbing to hold the parts together while the curing process takes place. The various members of which the tires are composed are vulcanized by being heated with steam, and sulphur is included in the rubber compounds in proper quantities to permit them to become firmly welded to the friction fabric layers between which they are placed.

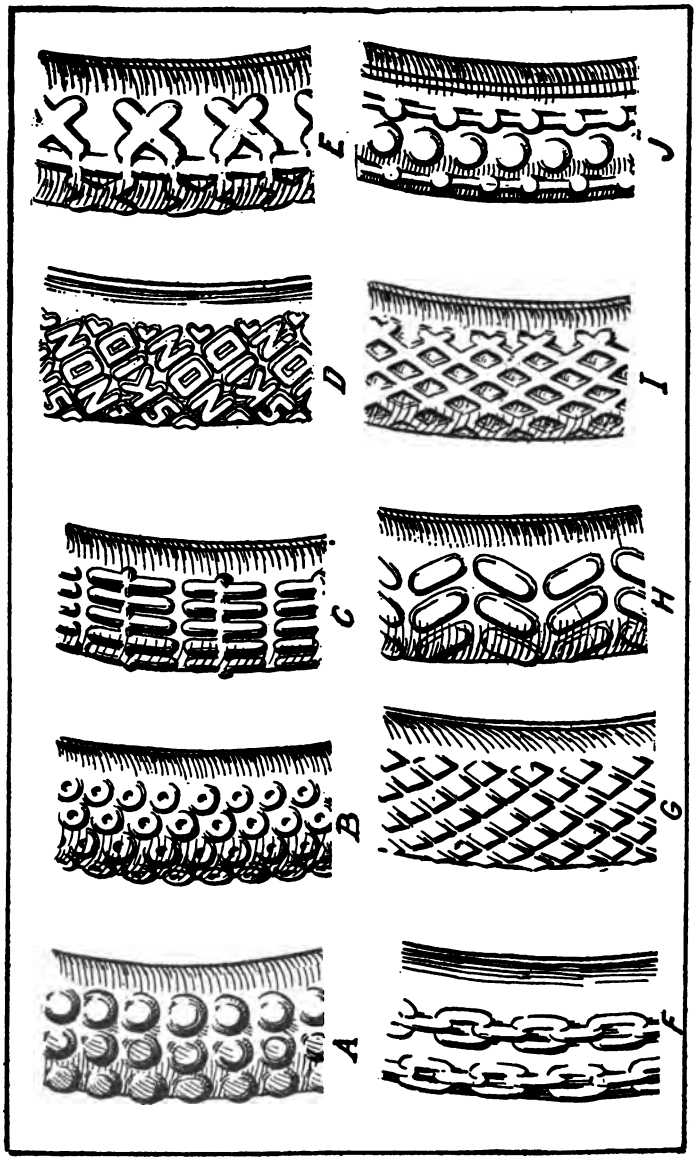


Fig. 230.—Standard American Anti-Skid Treads of Various Designs Showing Methods of Obtaining Rough Treads.

Q. What is the advantage of a smooth tread tire and under what conditions is it inadequate?

A. Smooth tread tires are simpler to make and cheaper to buy than the various anti-skid tread types and are the most suitable for general use on dry, hard roads. They have superior adhesion and the tread will wear much more uniformly than do "rough tread" tires. One disadvantage of the smooth tread casing is that it will not provide sufficient traction on slippery roads and a car is apt to skid more under these conditions than if it is provided with rougher or irregular tread tires which have a better grip on soft roads.

Q. What are features of various "rough tread" tires?

A. The most important feature gained by the use of rough treads is the elimination of a large degree of skidding and more positive traction under certain conditions of operation. The leading types of anti-skid tires are outlined at Fig. 230 and it will be apparent that there are many ways of obtaining the desired end. For the most part, various irregularly shaped projections or studs of rubber compound are moulded on the tread, these varying from simple round buttons or elongated bars to more complex forms composed of stars or imitating basket-weave or chains and one maker even goes so far as to mould a series of letters on the tread which imprints the words "Non-Skid" in mud or other such yielding road material. The most practical forms are those in which the projections are of sufficient size to prevent rapid wear.

Q. What is the inner tube, and of what material is it made?

A. The inner tube or air bag of the tire is composed almost entirely of pure Para rubber having only enough sulphur in the composition to insure the proper degree of curing. The inner tube is very elastic and is air tight and can be inflated to several times its normal diameter without danger of rupture. It is not suitable to resist wear as the resilient rubber of which it is composed would soon be destroyed if it came in contact with the road surface so it is protected by the more strongly constructed casing or shoe.

Q. What prevents chafing between inner and outer tire members?

A. As the inner tube is fully inflated, it entirely fills the space inside of the outer casing and there can be but little relative movement. In order to prevent chafing it is customary to use talcum powder as a lubricant to prevent friction between inner and outer members.

Q. What are tire lugs and where are they used?

A. When clincher tires are applied to heavy cars capable of high speeds it is customary to supplement the natural wedging action of the fully inflated inner tube forcing the tire beads in the rim channels by means of security bolts. These have an approximately Y-shape and are depended on to force the bead firmly into the rim channel at four or six points on the wheel periphery. The shank portion of the security member is a threaded bolt passing through the wheel rim and felloe and screwed in place by a wing nut. The head portion of the security member is V shape, composed of rubber or fabric built around a central metal core of sufficient size to bridge the gap between the two beads and hold them firmly into the channel. At the present time quick detachable tires are given preference and tire lugs are seldom used because the lighter cars using clincher tires do not need them.

Q. What is the life of outer casings?

A. The amount of service received from an outer casing, assuming that it is made of proper material and cured in a careful manner, depends upon many conditions, some of which are under the direct control of the operator, while others are unavoidable. The factors of car weight and speed are important and casings invariably last longer on light, moderate speed cars than they do on heavy high speed vehicles. On heavy touring cars a casing that receives average attention is considered to have rendered satisfactory service if the tread will not wear down to the fabric until 2,000 to 3,000 miles have been covered. On lighter cars casings have been known to run from 5,000 to 6,000 miles without becoming weakened sufficiently to require removal.

Q. What precaution must be taken to secure proper mileage?

A. Tire makers all recommend that the tires be examined carefully from time to time in order to observe a few simple rules. The

casings should be looked over to see if there are any serious cuts or bruises penetrating to the fabric and allowing water to find its way into the textile material and cause it to rot. The tires should also be properly inflated as it is claimed that fully 75% of all tire troubles outside of those due to natural depreciation are caused by insufficient inflation and overloading of tires.

Q. What are the best tire sizes for various vehicle weights?

A. Each size of tire is designed to carry a specified weight and as many times cars are equipped with tires which are barely up to the requirements, the following table recommended by the U. S. Tire Company will act as a guide to enable the motorist to see if the proper size of tire has been provided by the car manufacturer. The cars are to be weighed without passengers or luggage and each end of the car is to be weighed independently of the other. This is done by selecting a point on the frame midway between the two axles, and marking it in some way so that it can be easily distinguished. The front end of the car is then run on the usual form of heavy platform coal or hay scale, until the mark indicating the central position is just over the edge of the scale. This weight gives the approximate amount to be carried by the two front wheels. The car is then reversed and run over the scales until the rear parts rest on the platform. This weight as indicated on the scale beam shows the amount of load carried by the two rear wheels. The entire car is then placed on the platform and the total weight taken to see how it checks up with the sum of the two previous readings, which thus provides an approximately accurate check on the correctness of the first trial.

Tire Sizes and Suitable Loads.

	Rear Weight per Wheel.	Front Weight per Wheel.
28 x 2½	225 lbs.	275 lbs.
28 x 3	350 "	425 "
30 x 3	375 "	450 "
32 x 3	375 "	450 "
28 x 3½	425 "	500 "
30 x 3½	450 "	550 "

	Rear Weight per Wheel.	Front Weight per Wheel.
31 x 3½	475 lbs.	575 lbs.
32 x 3½	500 "	600 "
33 x 3½	525 "	625 "
34 x 3½	550 "	650 "
36 x 3½	600 "	700 "
30 x 4	625 "	750 "
31 x 4	635 "	775 "
32 x 4	650 "	800 "
33 x 4	675 "	850 "
34 x 4	700 "	875 "
35 x 4	735 "	885 "
36 x 4	750 "	900 "
40 x 4	850 "	1000 "
42 x 4	900 "	1050 "
32 x 4½	750 "	950 "
34 x 4½	900 "	1125 "
35 x 4½	935 "	1175 "
36 x 4½	975 "	1225 "
37 x 4½	1010 "	1260 "
38 x 4½	1050 "	1300 "
42 x 4½	1200 "	1450 "
34 x 5	950 "	1200 "
35 x 5	1000 "	1250 "
36 x 5	1050 "	1300 "
37 x 5	1100 "	1350 "
39 x 5	1200 "	1450 "
43 x 5	1400 "	1550 "
37 x 5½	1150 "	1400 "
38 x 5½	1200 "	1450 "

Q. Is there any relation between tire size and inflation pressure?

A. There is a very definite relation between the amount of air pressure for the various sizes of tires. As a rule, the larger tires which are heavier in construction and are depended on to carry the greater weight must be blown up to a greater degree than the smaller

and lighter tires. The following table shows the proper air pressures for various sizes of tires. A simple way to remember these pressures is to bear in mind that there should be twenty pounds air pressure for each inch of tire diameter.

Tire Inflation Table.

2½ inch tires	50 lbs.
3 " "	60 lbs.
3½ " "	70 lbs.
4 " "	80 lbs.
4½ " "	90 lbs.
5 " "	100 lbs.
5½ " "	110 lbs.
6 " "	120 lbs.

Q. What happens if tires are not sufficiently inflated?

A. If tires are not filled with the proper amount of air they will be distorted unduly under load and the fabric and rubber plies of which the casing is composed will be subjected to serious bending which may cause the various layers to separate from each other, this weakening the casing.

Q. What is the result if tires are too highly inflated?

A. If tires are pumped up too much the construction is subjected to stress that it was not designed to withstand and the inner tube will "blow out" through any weak point in the casing. Hard tires also subject the mechanism to considerable vibration because they are not sufficiently resilient.

Q. Which tire should be larger, the front or rear?

A. As a rule, the greater strain is taken by the rear tires because these members carry the larger portion of the car weight and in addition are depended upon to furnish traction and propel the vehicle. The front tires on most cars can be made smaller than the rear ones if desired, because they are called upon to support less weight and are not subjected to the wear resulting from skidding, driving stresses and braking reaction.

Q. Why are tires usually made the same size on automobiles?

A. It is common practice to make the front and rear wheels the same size on most American cars because there is very little difference possible between front and rear shoes with the average weight distribution. If two different sizes of tires are used, one must carry two spare casings and two different sizes of inner tubes to make satisfactory repairs. Then again, there is no way of equalizing the wear on the tires. If the casings are the same size, the front tires may be used to replace the weaker rear shoes and these members in turn transferred to the front wheels after a car has been in operation for a time. Rear tires invariably wear faster than front ones, so that after they have worn to a point where they are considered weak for the rear wheels they may have ample strength for the lighter duties at the front end of the car and the front tires, which are in better condition, may be placed on the rear wheels.

Q. How is air introduced in inner tubes?

A. Air is usually pumped into the inner tubes by hand or power operated air pumps of a portable pattern that is carried as part of the equipment of the car. A simple form of check valve is used at the tube that permits one to pump air into the tire but which seats automatically by pressure from within the tube to prevent air from escaping.

Q. Are there any substitutes for air?

A. Various compounds have been devised that are intended to be introduced into inner tubes or outer casings to take the place of air but none of these are practical because they are not sufficiently resilient and many of them are compounds that are actually injurious to the rubber of which the tire is composed. Some of these are affected by heat while others will flatten out at the point of contact between the tire and the ground if the car is left standing for any length of time.

Q. What are puncture proof pneumatic tires and how are they made?

A. Various attempts have been made to devise puncture proof

pneumatic tires by using leather or leather and metal treads applied to the tires of the conventional pattern or to imbed a series of metal discs overlapping each other like scales on a fish in the tread of a tire before this is cured. Most of these tires have a grave defect of generating considerable heat while in use and owing to the stiffness of the composite metal and leather or metal and rubber tread much resiliency is sacrificed.

LESSON TWENTY-FIVE

AUTOMOBILE BEARINGS AND THEIR CARE

Q. What are the functions of a bearing?

A. Bearings are used to support the various revolving shafts that are called upon to transmit power from one part of the motor car to the other and are needed to support rotating parts of all machines.

Q. Name principal types of bearings.

A. Bearings may be divided into two general classes, plain and anti-friction types.

Q. Where are plain bearings used?

A. At the present time the use of plain bearings is confined principally to the power plant and various unimportant points on the motor car chassis.

Q. Why are anti-friction bearings utilized?

A. Considerable power is absorbed at the bearing points when a shaft runs in a plain journal or bushing because considerable friction is present due to the sliding of the surfaces over each other. With bearings of the anti-friction types rolling friction is substituted for sliding friction and much less power is absorbed.

Q. Where are anti-friction bearings used in preference to plain journals?

A. Anti-friction bearings are used at practically all points of the mechanism where it is desirable to employ bearings that will not need continual attention and lubrication and that will absorb but very little power when subjected to heavy loads. Anti-friction bearings will carry stresses without depreciating that would soon produce deterioration of the most efficient plain journals.

Q. What materials are used in making plain bushings?

A. The shafts used in motor car construction are generally of steel and the surrounding boxes or bushings of parts that have severe duties to perform are generally of bronze, Babbit metal, or other anti-friction metals of this nature.

Q. What precaution is essential to insure continued service from plain bearings?

A. The bushings or boxes of a plain bearing must be accurately fitted to the shafts they are to bear against, yet must have sufficient space to provide a film of oil between the working surfaces. Positive means of supplying lubricant must be used because it is really the film of oil between the two surfaces that acts as a friction reducer and makes the plain bearing practical.

Q. What causes overheating of plain bearings?

A. Overheating of plain bearings is generally due to lack of lubrication or the use of poor lubricant. If the bearings have just been refitted the overheating may be caused by a binding due to too intimate contact between the bushings and the shaft they encircle, which does not permit the introduction of an oil film to absorb the heat generated by friction.

Q. Why are soft metal bearings more suited than hard bronze bushing for general use?

A. The use of soft metals, such as Babbit or white brass is preferred by many designers because these not only have superior friction reducing qualities in themselves but have a low enough melting point so that if lubrication fails and friction heat is developed the metal lining of the bearing will run and will not injure the shaft. With hard metal such as bronze any impurities or abrasive matter in the oil will produce rapid cutting of the surfaces and if a bearing heats up it will not only score the bushings but will cut deep grooves in the shaft journals which are usually costly to repair. New white metal linings may be easily inserted because the shaft is not damaged. Soft metal boxes are also easier to fit to a shaft and will adapt themselves better to irregularities on the journal surface than will the hard material. Hard bronzes or hardened steel bush-

ings must be used at points subjected to considerable heat or where much stress is to be supported by a bearing having relatively small size.

Q. Where are soft metal bearings commonly used?

A. In most automobile power plants the main bearings of the crankshaft and the lower connecting rod bearings are generally of soft metal while the upper end of the connecting rod, camshaft bearings, and various small bearings supporting timing gears, magneto and pump drive gears, and other minor shafts of this nature utilize bronze or hardened steel bushings. A soft metal can only be used where ample bearing surface is provided because it is easier to deform it under load than hard metals.

Q. How are soft metal bearings inserted in boxes?

A. On a number of the cheaper engines the Babbit metal is poured into the shell cast integral with crankcase to receive it and a mandrel of steel smaller than the shaft diameter is employed as a core piece around which the melted metal is poured. Soft metal boxes are sometimes die cast in the form of bushings which may be inserted in machined housings or boxes provided to receive them.

Q. What are "die-cast" bearings?

A. "Die-cast" bushings are components formed by pouring molten metal in a mould composed of two pieces of steel machined very accurately so that the surface of the casting is smooth and true to the mould. In order to insure positive filling of the mould with hot metal it may be forced in under pressure which insures that every little corner will be reached. Die-castings are well suited as bearings because they may be moulded true enough to size, so practically no finish will be necessary.

Q. How are plain bearings fitted to shafts?

A. Plain bearings may be fitted to shafts in two ways. If the bushing is a solid form it is usually smoothed out after boring by a tool known as a reamer which enlarges the bore so it is a few housandths of an inch larger than the shaft diameter. Boxes of arge size are usually of the divided pattern and are fitted by a craping in" process.

Q. Describe "scraping in" bearings.

A. The process of scraping bearings is a simple though tedious one that requires some degree of mechanical skill. The shaft to be fitted in the boxes is covered with a light film or coating of Prussian blue or other pigment and is allowed to rest in the box and then revolved. Any high spots in the bearing will scrape the blue from the shaft and the color indicates the points on the bushing that contact with the shaft. When the shaft is first inserted in the box it may bear

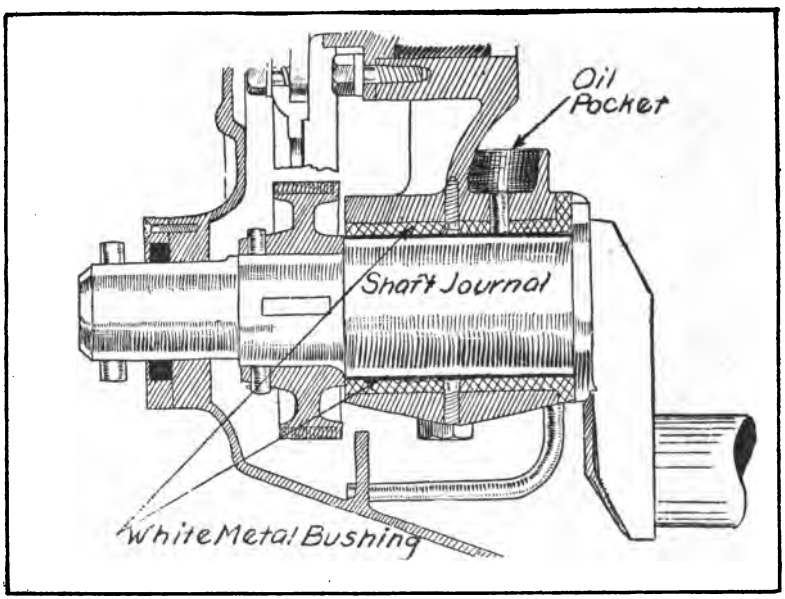


Fig. 231A.—Engine Main Bearing of Plain Bushing Type.

at only one or two points. These are eliminated by sharp hardened steel instruments having cutting edges that scrape away the high spots. The bearing is tested after every scraping operation with the piece of shaft it is to encircle and it has been scraped to a suitable fitted surface when the shaft bears practically in the entire bushing, which condition is reached when the blue color is distributed uniformly over the surface of the bushing. The white metals are easier

to scrape than the bronzes and for this reason are widely used where bearings must be fitted by this process.

Q. Name principal types of anti-friction bearings.

A. Anti-friction bearings are those in which rolling friction is substituted for sliding friction and are shown clearly at Fig. 231.

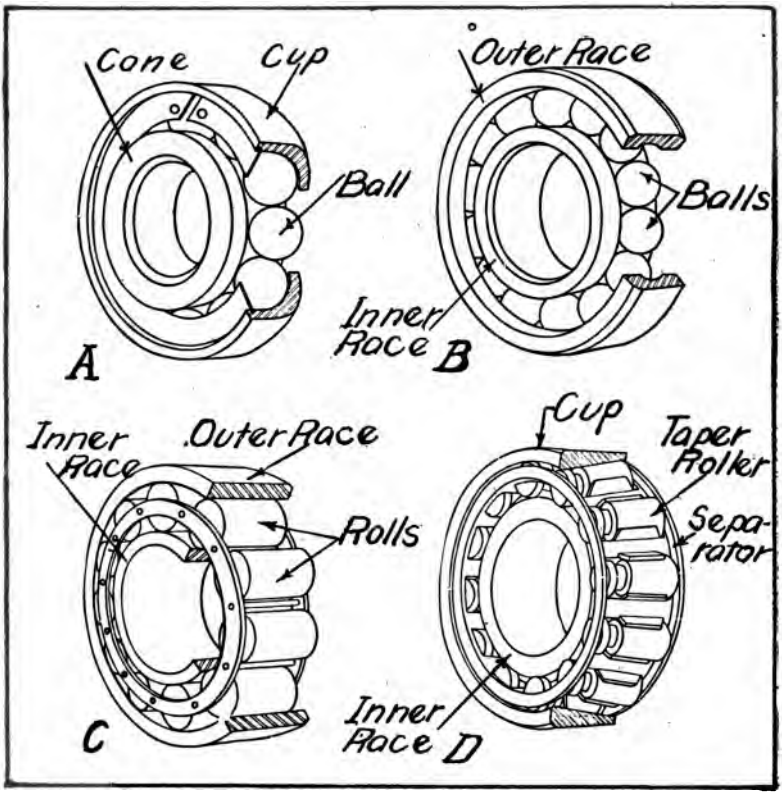


Fig. 231.—Representative Types of Anti-Friction Bearings.

All anti-friction bearings may be divided into two general classes, those employing balls, as shown at *A* and *B*, and the other types which use rollers to support the load as shown at *C* and *D*.

Q. Name principal forms of roller bearings.

A. The principal types of roller bearings that have received

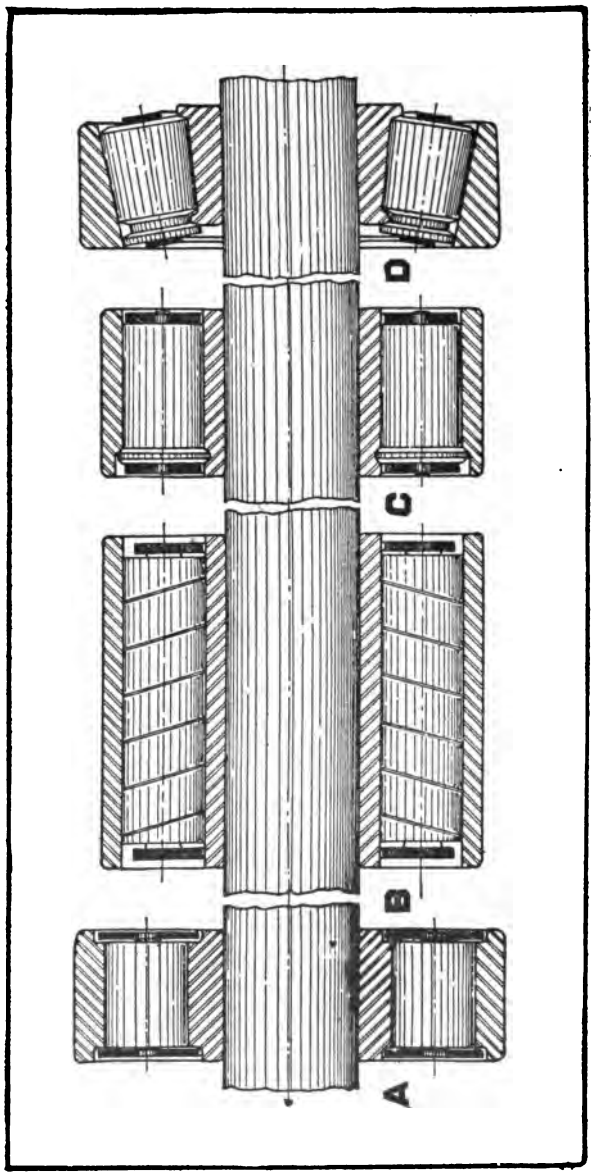


Fig. 232.—Outlining Design of Leading Forms of Roller Bearings.

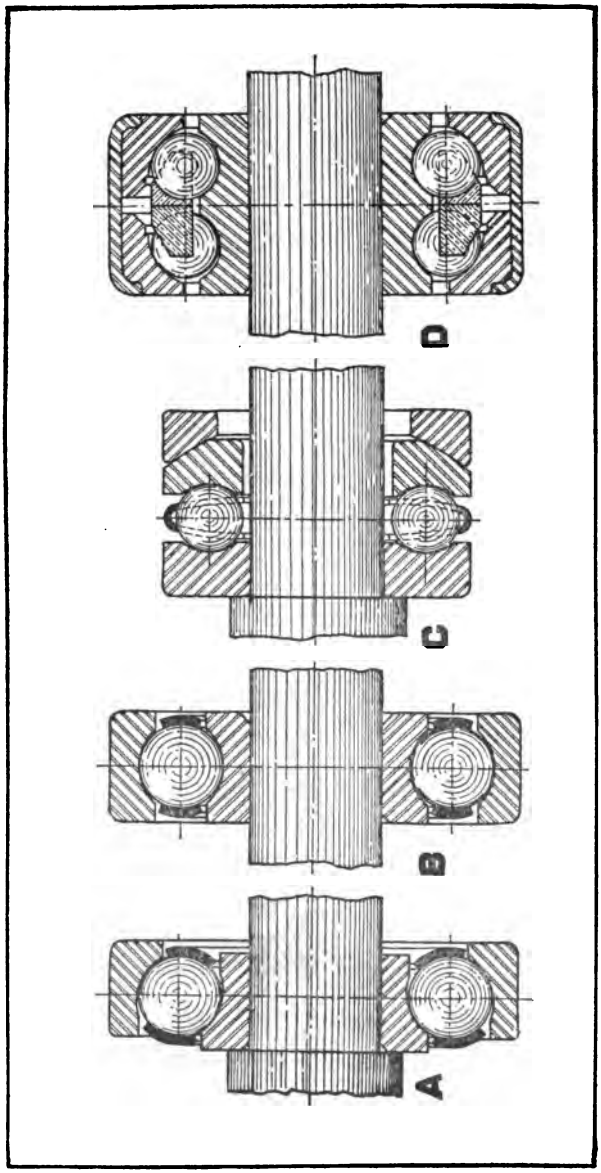


Fig. 233.—Forms of Ball Bearings That Have Received General Application.

general application are clearly outlined at Fig. 232. The forms shown at *A* and *B* utilize straight rollers, those in bearing *A* are solid stock while those in bearing *B* are flexible hollow members. The type at *C* uses solid rollers that have an upturned flange fitting suitable recesses in the inner and outer races designed to hold the parts in engagement if the bearing is subjected to an end thrust. The type at *D* is a very popular form employing tapered rolls and is capable of working efficiently under an end thrust that could not be adequately resisted by bearings using straight rolls.

Q. Name principal types of ball bearings.

A. The principal types of ball bearings are shown at Fig. 233. That at *A* is a cup and cone form patterned somewhat after bearings that have received wide applications in bicycles and numerous other light machines. This bearing has an angular contact and is a combined radial and thrust bearing. That shown at *B* is a single row annular form having a vertical load line and is used principally for radial loads. That shown at *C* is a thrust bearing, while that outlined at *D* is double row form capable of taking loads from any direction. The bearing at *A* is more suited for angular loads than any other while those at *B* and *C* are suited for radial and thrust loads respectively. The bearing at *D* will take either radial or thrust stresses.

Q. What loads are bearings subjected to?

A. Bearings of all types are subject to three main loads as clearly outlined at Fig. 234. These in order of their importance are radial load, angular load, and end thrust.

Q. Define radial load.

A. A radial load is one that is exerted in a straight, vertical line at right angles to the horizontal center line of the shaft.

Q. What is an angular load?

A. An angular load is one composed of radial and end thrust components and is applied at an angle instead of radially or parallel to the shaft axle.

Q. Define a thrust load.

A. Any force applied in a direction parallel to the shaft axis is termed "end thrust."

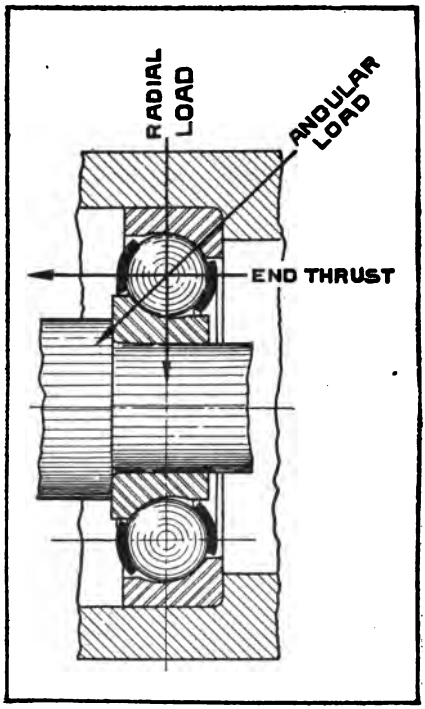


Fig. 234.—Showing Character and Direction of Loads Bearings May Be Subjected To.

Q. How is thrust resisted when plain radial bearings are used?

A. If plain radial bearings of the annular ball or straight roller type are used at a point subjected to end thrust as well it is necessary to supplement these bearings with a ball thrust member, as shown at Fig. 233-C designed especially for this purpose.

Q. What type of roller bearings can resist thrust and radial load?

A. A roller bearing of the tapered roll form, as outlined at Fig. 232-D, is capable of resisting end thrust as well as radial loads but the thrust must be applied in a direction that will tend to force the bearing parts more closely together as shown at Fig. 235-B. With a bearing of the straight roller form as at Fig. 235-A any load applied in a direction parallel to the roll or race surface, as indicated by the arrows, will tend to force the bearings apart unless resisted by some form of thrust bearing. With the form of bearing shown at *B*, if the cup or outer member is held and the load is exerted against the cone or inner member it will tend to force the rolls more tightly between the races and this prevents further movement.

Q. What simple type of ball bearing can take thrust as well as radial load?

A The cup and cone type of ball bearing having an angular load line outlined at Fig. 233 corresponds to the tapered roller bear-

ing inasmuch as it is capable of withstanding a one-direction thrust as well as a radial load. As is true of the tapered roll member the load must always be applied in a direction tending to bring the parts of the bearing into more intimate contact.

Q. Can a unit bearing be made to take end thrust from both directions and sustain a radial load as well?

A. The double row bearing outlined at Fig. 233-D is an assembly composed of two cup and cone bearings having a common inner race member with independent cup members securely held by a steel

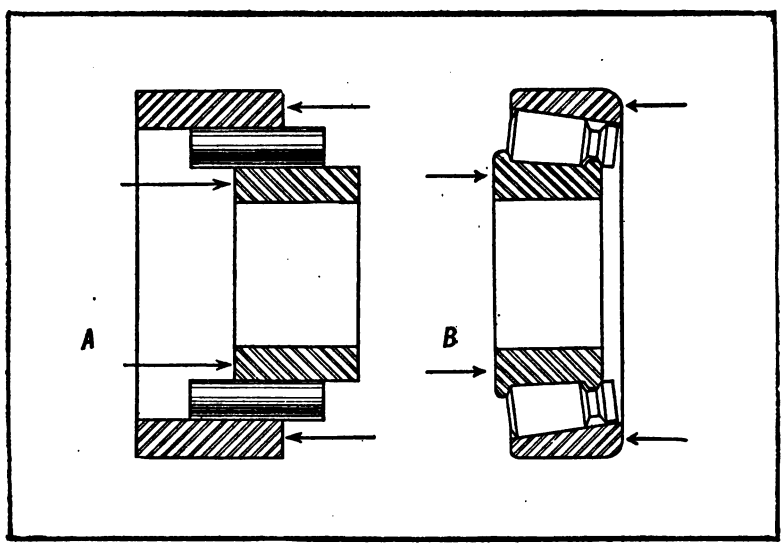


Fig. 235.—Showing How Taper Roller Bearing Can Stand End Thrust.

shell and is capable of taking a load from any direction. As the load lines are at an angle and diverge from the center line of the bearing a load applied from any direction cannot produce disassembly of the parts. A radial load will be taken by both rows of balls, while a thrust load from either direction will be resisted by the outer race and ball opposite the point of application, assuming that the outer race is held against an abutment or shoulder in the housing

while the load is applied to the cone. If the cone or inner member is held against a shoulder on a shaft and the load is applied to the outer race it will be resisted by the row of balls nearest the line of thrust.

Q. How does angularity of load affect radial and thrust capacity?

A. The angularity of the load line of a bearing affects radial and thrust capacity depending upon the angle the load line assumes with the horizontal or vertical center lines of the bearing. As a bearing with a vertical load line has the greatest radial capacity and practically no thrust resistance and one with a horizontal load line has the greatest thrust capacity and practically no radial capacity it will be apparent that as the load line approaches the vertical the radial capacity increases and the thrust capacity decreases and *vice versa.*

Q. What are the principal types of straight roll bearings?

A. Straight roll bearings may be divided into two principal types, those having solid rollers and others utilizing flexible members.

Q. Outline features of solid and flexible rollers.

A. A solid roll bearing must use a short roll in order to prevent distortion and deflection of rolls. If long solid rollers are used they are apt to break if the load is not applied evenly along their entire length because as the roll flattens slightly under load, one end will tend to travel faster than the other and this produces friction between the rolls and the retaining cage. The capacity of a solid roll is greater than that of a flexible member outlined at Fig. 236 but it is contended by adherents to the flexible roller construction that this type adapts itself more readily to irregularities in shaft contour and thus turns with less friction than do the solid rolls.

The flexible roller bearings are made in two types, that outlined at *A* Fig. 226 being the regular pattern in which long steel rolls are used while that at *B* which is termed the "high duty" type uses shorter rolls of high tensile strength alloy steel and accurately ground inner and outer race members. In the regular long roll

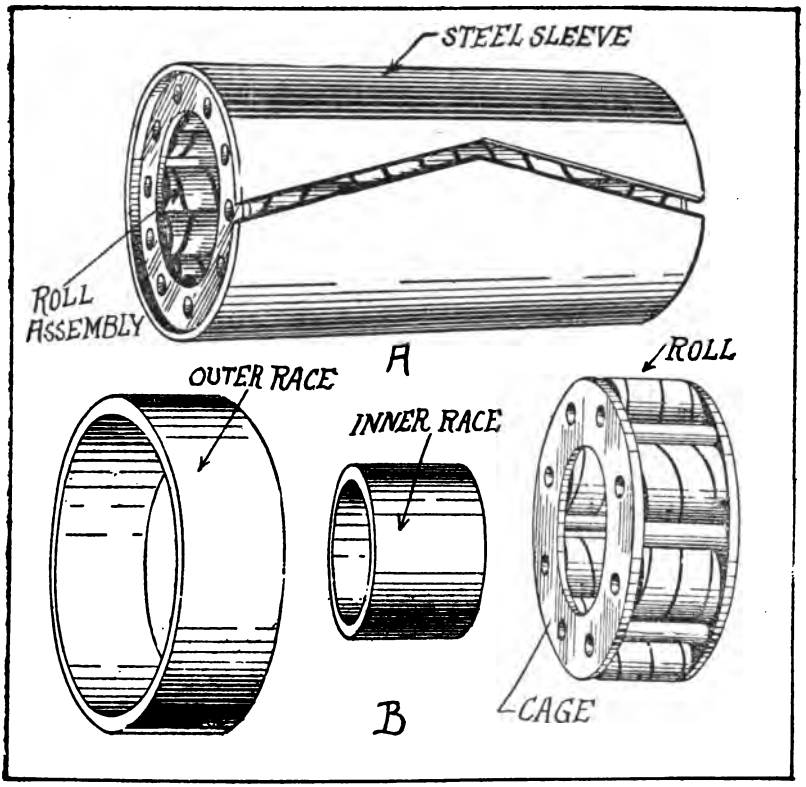


Fig. 236.—Outlining Construction of Hyatt Flexible Roller Bearings.

pattern the shaft itself is intended to form one bearing surface and as this is generally soft the rolls must be long in order to distribute the load over more surface. Another advantage of moment for the flexible roller bearings as opposed to the solid roller type is the way the rolls are formed by winding a narrow strip of flat steel around a mandrel to provide a space between the convolutions that acts as a very efficient oil carrier as it rotates. Alternate rollers are wound with right and left spirals so the oil will not be forced clear of the bearings but will be constantly circulated from one side to the other.

Q. What is the difference between a ball and roller bearing and which has the most friction?

A. In either ball or roller bearings the effect of the load is to flatten the supporting members a very small amount so that in a roller bearing the contact between the roll and the raceway may be represented by a rectangle having a length equal to the roll but a width so small that it is usually considered a line contact. In a ball bearing the flattening of the ball produces an ellipse of such small area that it is usually considered a point of contact. As the

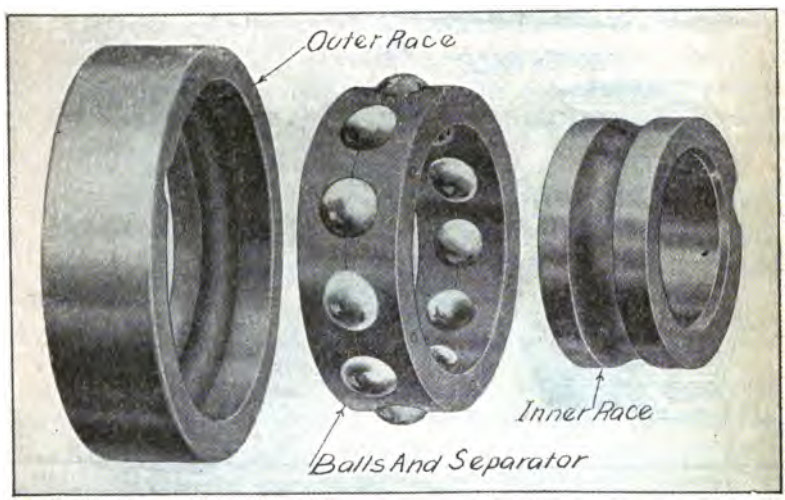


Fig. 237.—Parts of Typical Single Row Ball Bearing.

reduction of friction depends upon the amount of surface in contact it can be readily understood that the form having the least amount of contact would have less friction than the other though its capacity would also be lower than that of a roll of equal diameter but having contact along the entire length. Ball bearings are generally employed where it is desirable to reduce friction to a minimum and where bearings must attain high speed. Roller bearings have been widely applied where bearings of relatively small diameter but of large carrying capacity must be used, where the shafts revolve at

comparatively low speed and where maximum bearing efficiency is not important.

Q. Name important parts of any anti-friction bearing.

A. The important parts of an anti-friction bearing of the roller form are shown at Fig. 236-B, while those of ball bearings of the radial and double row types are outlined at Figs. 237 and 238. The principal parts are an inner race, a number of supporting anti-friction or rolling elements, a suitable cage or separator to contain them and an outer race to act as path for the rolls or balls.

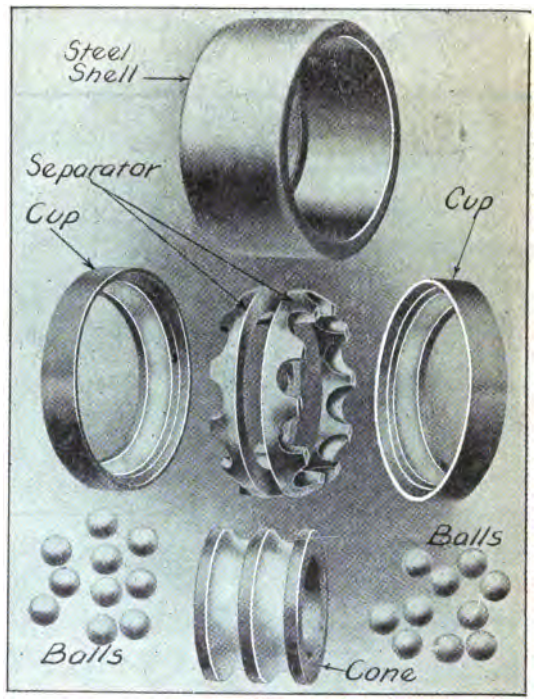


Fig. 238.—Important Components of Double Row Ball Bearing.

Q. Why is the separator or cage necessary?

A. A ball or roller bearing may be made of the full type, i. e. proportioned so that practically no space shall exist between the balls or rollers. This introduces an undesirable element of friction, due to the rubbing of one revolving member against its neighbor, so most anti-friction bearing designers provide a cage, container or separator, that is depended on to separate the rolls or balls from each other.

Q. What are separators made from?

A. The design of the separator and the function it is intended to perform determine the materials to be used in its construction. A cage or retainer that is depended on to carry the balls or rolls and not to actually keep them separated from each other may be made of stamped steel while those forms that are intended to separate and guide rolling members usually pocket them in an oil filled individual chamber for each member and are generally die cast of bronze or white metal.

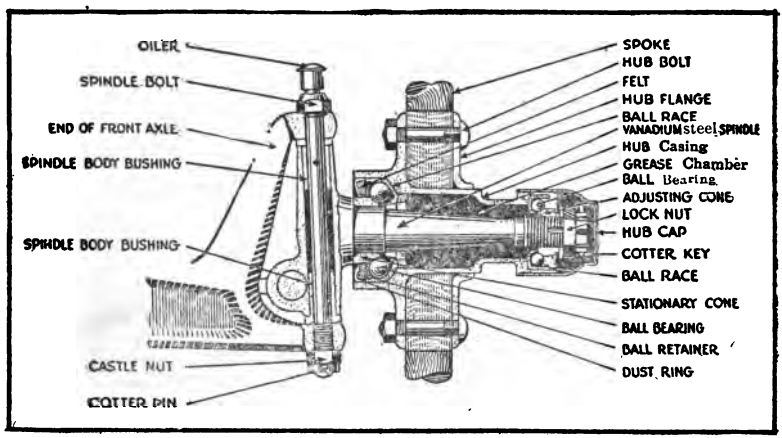


Fig. 239.—Front Hub of Ford Model T Mounted on Cup and Cone Type Ball Bearings.

Q. What other function besides separating the balls or rolls must the separator perform in a "take down" bearing?

A. In a bearing of the cup and cone or taper roller type the separator also acts as a retainer to prevent the rolling elements coming out of place if the bearing is taken apart.

Q. Are annular radial type ball and roller bearings adjustable for wear?

A. Annular ball bearings having vertical load lines and roller bearings having straight rolls are not adjustable for wear.

Q. How is the factor of deterioration made negligible in annular bearings?

A. Annular bearings of the non-adjustable type are very accurately constructed and are made of material having a high elastic limit and great strength. As there is but little friction between the highly finished, accurately machined and fitted parts of a well made annular bearing there will be practically no wear and if the bearing is not overloaded and is properly lubricated the factor of depreciation will be negligible.

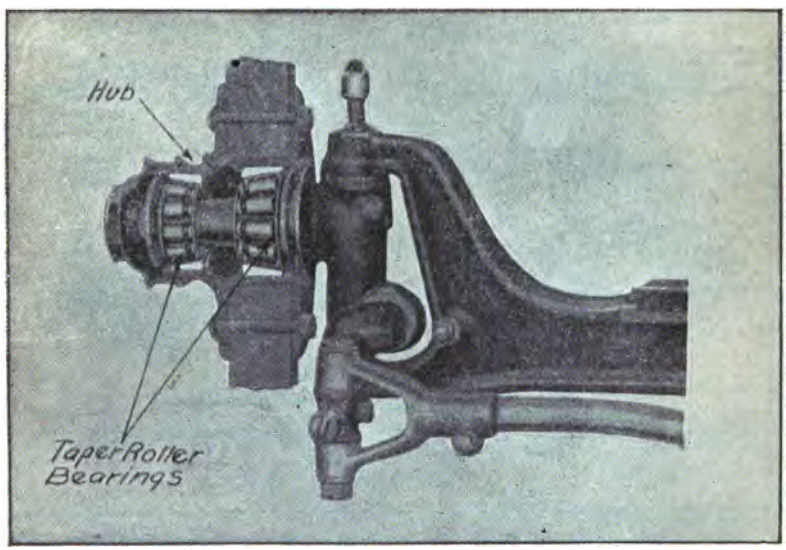


Fig. 240.—Front Hub With Timken Roller Bearings.

Q. What advantages have "take-up" bearings over the straight radial type, and wherein are the latter superior to the former?

A. When cup and cone ball bearings as outlined in a front hub at Fig. 239 or tapered roller bearings as shown at Fig. 240 are used it is possible to take up any looseness existing between the parts by screwing up on an adjusting nut that will bring the cone or inner member closer to the outer member which effectively eliminates lost

motion. Bearings of this type may be easily removed for inspection and can always be adjusted by an experienced person so they will turn with minimum friction and with absolutely no lost motion. When used in front hubs in the manner indicated the combination of the two bearings which have diverging load lines from the center produces a hub mounting capable of withstanding end thrust from either direction and support a radial load as well. Bearings of the straight radial type would not be suited for this application

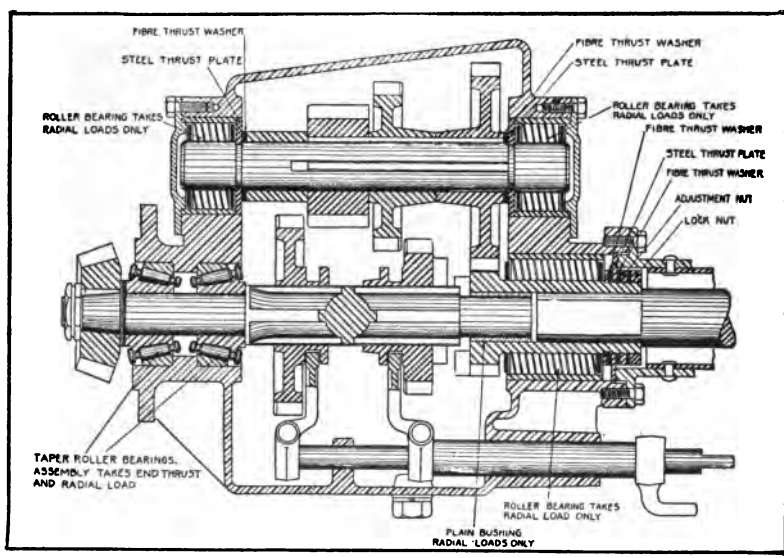

FIBRE THRUST WASHER
STEEL THRUST PLATE
ROLLER BEARING TAKES RADIAL LOADS ONLY
FIBRE THRUST WASHER
STEEL THRUST PLATE
ROLLER BEARING TAKES RADIAL LOADS ONLY
FIBRE THRUST WASHER
STEEL THRUST PLATE
FIBRE THRUST WASHER
ADJUSTMENT NUT
LOCK NUT
TAPER ROLLER BEARINGS. ASSEMBLY TAKES END THRUST AND RADIAL LOAD
ROLLER BEARING TAKES RADIAL LOAD ONLY
PLAIN BUSHING RADIAL LOADS ONLY

Fig. 241.—Gearbox With Shafts Mounted on Roller Bearings.

unless supplemented by forms capable of taking end thrust. A disadvantage of some moment sometimes advanced against the adjustable form of anti-friction bearings is that these may be adjusted too tightly or not tight enough by an inexperienced mechanician or novice motorist and the bearings be subjected to shocks and stresses that they were not designed to withstand, the result would be rapid depreciation and considerable friction at a point where this should properly be eliminated. When using annular non-adjustable forms of bearings these are received from the specializing

manufacturer as a perfectly adjusted, free running unit which cannot be varied because no provision is made for changing the adjustment provided by the manufacturer. The non-adjustable type is practically a "fool proof" bearing.

Q. Name parts of automobiles where radial loads only are present.

A. Radial loads are present only in certain portions of the engine and gearset of the average automobile. In most cars the

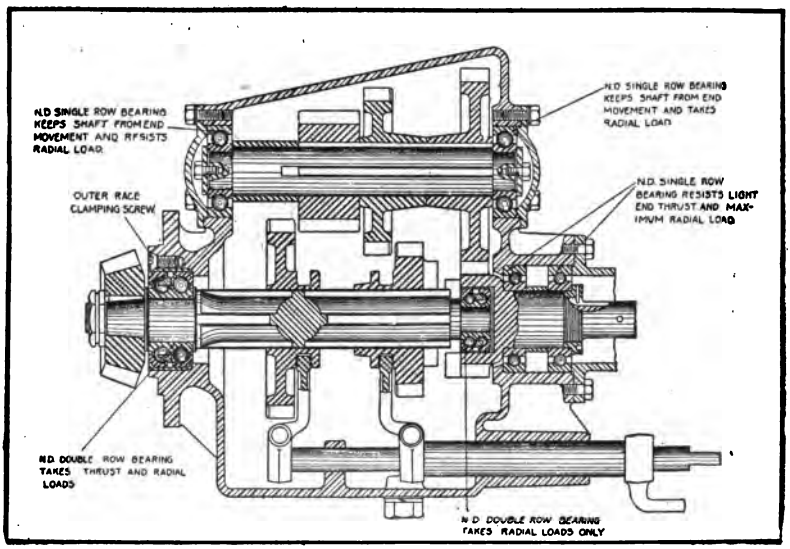

N.D SINGLE ROW BEARING KEEPS SHAFT FROM END MOVEMENT AND RESISTS RADIAL LOAD
OUTER RACE CLAMPING SCREW
N.D. DOUBLE ROW BEARING TAKES THRUST AND RADIAL LOADS
N.D SINGLE ROW BEARING KEEPS SHAFT FROM END MOVEMENT AND TAKES RADIAL LOAD
N.D. SINGLE ROW BEARING RESISTS LIGHT END THRUST AND MAXIMUM RADIAL LOAD
N.D. DOUBLE ROW BEARING TAKES RADIAL LOADS ONLY

Fig. 242.—Three Speed Gearset Using Ball Bearings.

connecting rod and crankshaft bearings are not subjected to thrust and the countershaft and main shaft of the gearset, unless this is incorporated as part of the rear axle, are subjected to practically only radial stress. In the illustration at Fig. 241 the use of flexible roller bearings on the countershaft, subjected to practically only radial loads, is outlined, while in Fig. 242 the application of single row annular ball bearings in a similar capacity is shown. In this form of gearset which is intended for attachment directly to the rear axle the bevel drive pinion is attached to and revolves with the

transmission main shaft. As a thrust load is present at this point, in the gearbox shown at Fig. 241 the rear end of the shaft is supported by a pair of tapered roller bearings while at Fig. 242 one double row ball-bearing performs the same function.

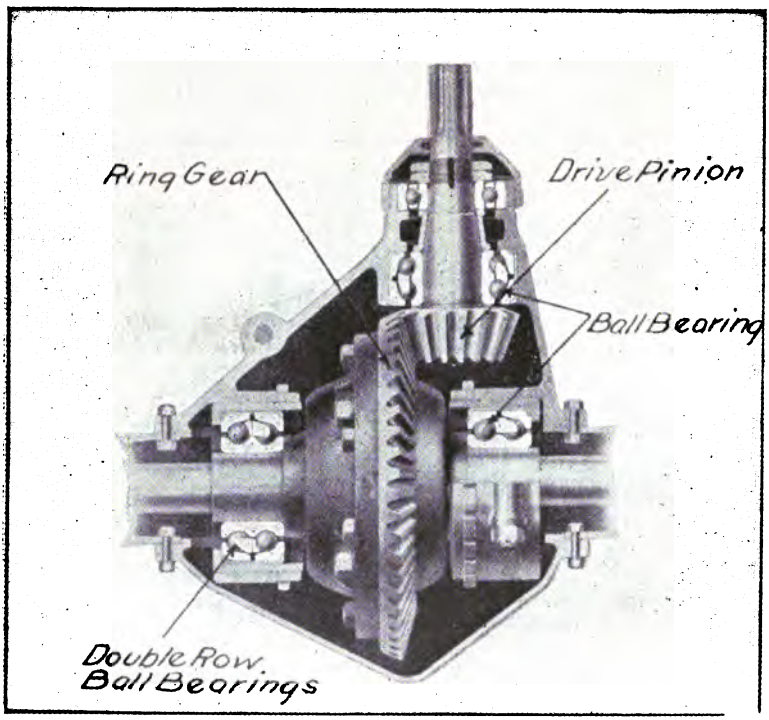


Fig. 243.—Differential and Driving Gear Assembly Supported by Ball Bearings.

Q. At what point is considerable thrust present?

A. Considerable end thrust in addition to radial load is present at the front wheels of an automobile, at the worm or bevel driving gearing and at the rear wheels.

Q. What types of bearings are suited for these points?

A. As previously explained bearings adapted to resist end thrust

and radial load should be used at all points where the load is really an angular resultant of radial and thrust components.

The bevel gear drive and differential assembly shown at Fig. 243 is mounted on double row ball-bearings which are capable of taking loads from all directions. These are used to support the differential casings to which the ring gear is attached as well as to take the main thrust load back of the bevel drive pinion.

Two forms of rear wheels are shown at Fig. 244, that at *A* is the hub of a wire wheel for pleasure car service in which the load is carried by ball-bearings of the adjustable cup and cone pattern. The heavy truck wheel outlined at *B* is mounted on a combination of single and double row bearings. The double row member is clamped so it takes the major part of the radial load and all of the thrust. The single row bearing, which is restrained only at the inner race, takes radial stresses solely.

Q. Can a radial ball bearing take thrust, and how much?

A. While the regular single row annular bearing having a vertical load line is not recommended to take end thrust it is capable of successfully resisting end thrust equivalent to 25% of its radial capacity.

Q. Name the three important American roller bearings and describe them.

A. Three roller bearings developed in America, where the perfection of this form of bearing has been carried to a fine point, are the Timken, Hyatt, and Bower. All other forms are practically modifications of these three main types. The Timken roller bearing is a form employing tapered rollers which we have previously described, the Hyatt uses the flexible plain rollers, while the Bower employs a straight roller with an upturned locating flange. The taper roller can take end thrust and radial load while the flexible roller is suited only for radial stresses.

Q. What is the conventional method of installing anti-friction bearing inner members?

A. The inner races of anti-friction bearings are usually machined so closely to standard sizes that various makes will interchange without difficulty. The shafts to which these races are fitted should

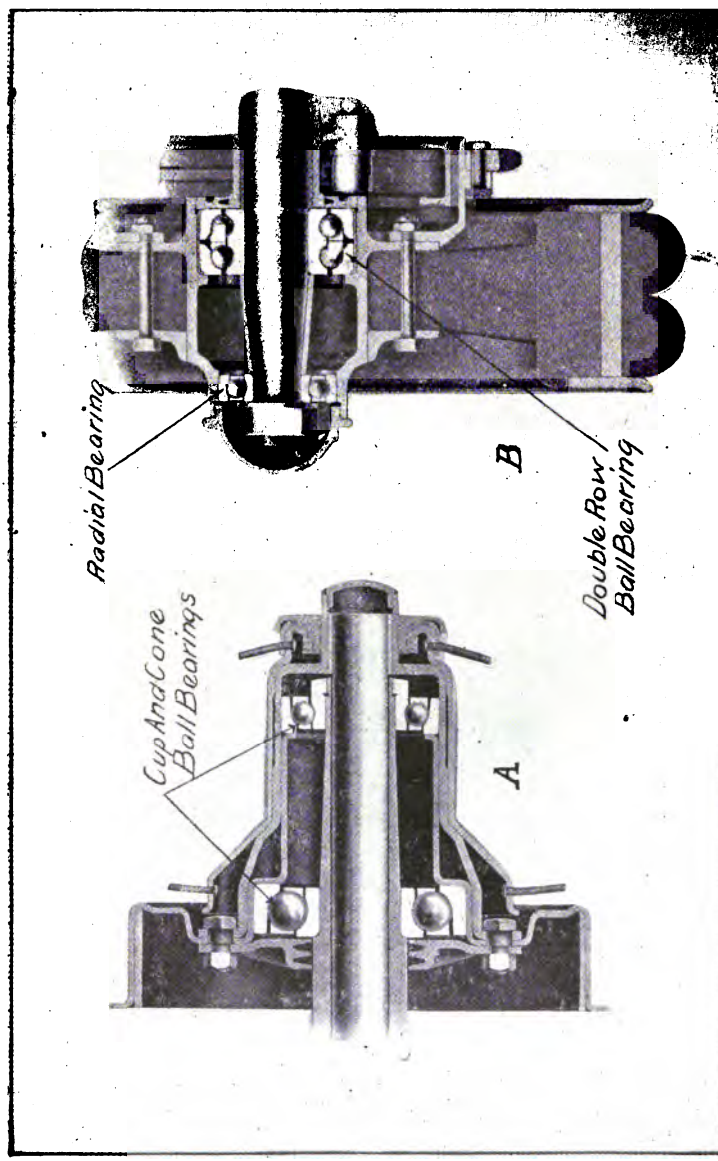


Fig. 244.—Outlining Two Methods of Applying Ball Bearings to Rear Hubs.

be machined with equal accuracy and should be just enough smaller than the bearing bore so that inner race will be an easy push fit on the shaft. It is customary to always restrain the bearing inner race from movement by means of a clamp nut or its equivalent. These are depended on to force the inner race firmly against a shoulder or tubular spacing member on the shaft, as outlined at Fig. 245.

Q. How are anti-friction bearing outer races secured?

A. If a bearing is to resist end thrust as well as radial load it is customary to clamp the outer race between a threaded closure member and a shoulder in the housing as shown at Fig. 245. The closure member, however, does not bear against the bearing outer race but a space of about .01 inch is allowed between the bearing outer race and shoulders on clamp nut and housing. An outer race is invariably a free push fit in the housing. If the bearing is to be subjected to only a radial load it is not necessary to clamp the bearing outer race.

Q. Why is it desirable to clamp bearing inner race to shaft?

A. The bearing inner races are clamped firmly to the shaft in order to prevent creeping of the inner race on the shaft under heavy loads as this would tend to wear the shaft and the bearing would not be held in place as firmly as it should be if the cone once started to turn around.

Q. When narrow single row bearings are to be housed in soft metal, what is a desirable precaution to take?

A. In order to prevent the narrow outer races, which are of hard steel, from peening the soft aluminum alloy of a gear case, for example, it is customary to house the outer races in a member of pressed steel, cast bronze or malleable iron which is firmly pressed into the soft metal case and which takes all the strain imposed on heavily loaded bearings.

Q. What is the best method of installing radial bearings when two are used on a shaft subjected to thrust?

A. Only one of the bearings should be employed to resist the thrust load and this should have both inner and outer races clamped.

The other bearing which is depended on to take only radial loads has a "floating" outer race but a clamped inner member.

Q. In assembling adjustable ball or roller bearings what precaution is necessary?

A. It is imperative that the parts of the bearing be adjusted to a nicety. The adjusting nut should be screwed up only to such

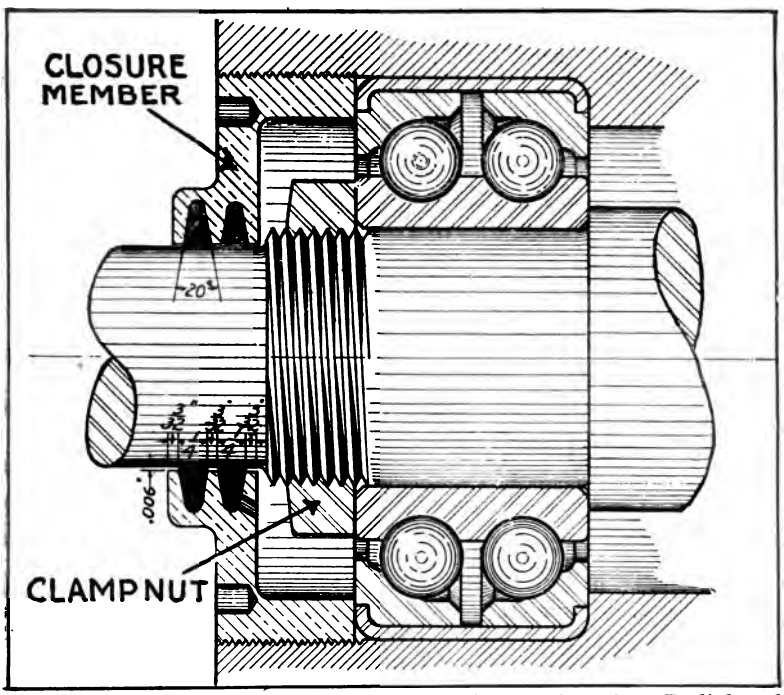


Fig. 245.—Method of Mounting Ball Bearing Subjected to Radial and Thrust Loads.

a point that absolutely all the lost motion or radial play is taken from the member supported and yet that member should be free to revolve without friction. If the bearings are tightened up unduly they will wedge and bind and wear out quickly. If they are not adjusted tightly enough the balls or rolls will be subjected to a series of hammer-like blows whenever the bearing is operated and this will also produce rapid depreciation of the bearing.

Q. How are ball or roller bearings lubricated?

A. The method of installation and the duties they are to perform are the factors governing the lubrication of anti-friction bearings. They are generally lubricated with high grade mineral oils and greases.

Q. What grade of oil is most suited for heavy loads and low speed?

A. A heavy bodied lubricant of the semi-fluid type is best adapted for use in bearings subject to heavy loads and revolving at low speed. Greases having about the consistency of vaseline or petroleum jelly are generally applied for this purpose.

Q. What grade of lubricant is best suited for light loads at high speeds?

A. If an anti-friction bearing is housed in an oil retaining, dust excluding housing, it is good practice to use a medium grade machine oil and run the bearings in a constant bath of lubricant. Heavier greases produce an item of friction, which while negligible in low speed bearings may be high enough to be objectionable in high speed forms.

Q. Why are animal or vegetable oils undesirable?

A. Ball or roller bearings should not be lubricated with oils of organic derivation because these are not stable enough. They oxidize or become rancid on exposure to the air and are apt to gum up in the bearing. Animal oils are also apt to contain fatty acids.

Q. Why are acidulous oils injurious?

A. Oils containing acid should never be used with ball or roller bearings because the acid will etch or discolor the highly polished surfaces of the anti-friction members and the races. This etching and rust deposits will interfere with smooth operation and tend to produce rapid depreciation of the bearings.

Q. Give some general precautions to be observed in installing anti-friction bearings.

A. Anti-friction bearings should always be installed in mountings that can be effectively closed to prevent escape of oil or entrance of dirt, grit and water. Ball bearings should never be driven in

place with a steel drift or hammer because the races are hard steel and are apt to be cracked unless they are forced in place either with a steady pressure from a press or by blows applied through the medium of a block of hard wood or piece of Babbit metal interposed between the hammer and the bearings. The blow should always be directed or the pressure exerted against the race that is being forced in place.

LESSON TWENTY-SIX

HOW TO START AND CONTROL AUTOMOBILE POWER PLANT

Q. Before starting automobile engines, what precautions are necessary?

A. The motorist should make sure that there is plenty of gasoline in the tank and that it is turned on so it will flow to the carburetor. The radiator should also be filled with clean water and the oiler must also receive attention. The gear shift lever is placed in the neutral notch and the emergency brake hand lever is locked in such a way that the brakes are engaged. The spark lever on the steering wheel is set at a retard position and the throttle or gas lever is slightly advanced. The switch for the ignition system is then placed in its active position.

Q. Why must radiator be filled?

A. It is imperative that there be enough water in the cooling system or the engine will soon become overheated.

Q. Why must oil supply be inspected?

A. If an automobile engine is run for any length of time without lubricant it will be seriously damaged, so before attempt is made to start the engine for a day's service it is well to see that there is an adequate supply of lubricant in the oiling system.

Q. Why must gasoline be turned on at the tank?

A. At the tank end of the pipe line conveying gasoline to the carburetor will be found a shut off valve as indicated at Fig. 246. If this valve is closed no fuel will reach the carburetor so it is important to open it up or see if it is opened before attempting to start the engine.

Q. Why must switch be closed?

A. The switch must be closed or placed in operative position so the current can flow to the spark plugs depended on to ignite the fuel in the cylinders.

Q. If both battery and magneto ignition are provided, which is preferable to start on, and why?

A. The switch lever should be placed on the battery side of the switch as indicated at Fig. 247-A because it is easier to start an engine with a battery spark than it is from the average magneto.

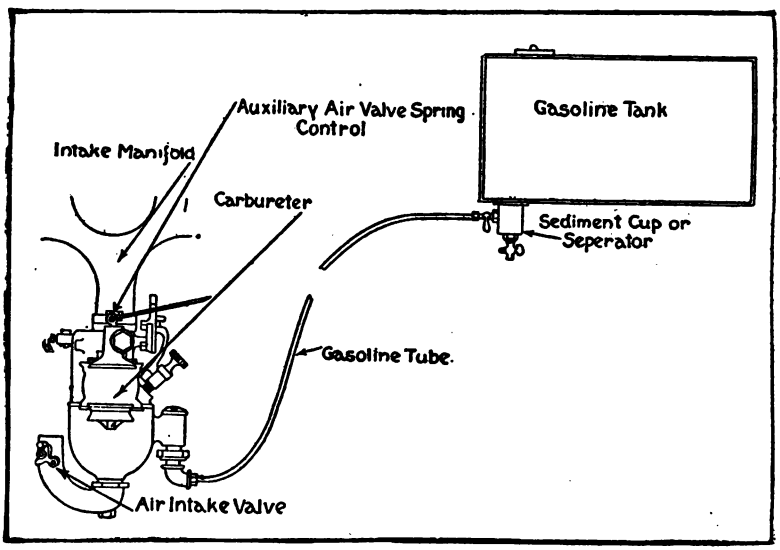


Fig. 246 – Typical Fuel System Showing Shut-off Valve at Tank.

With a battery the current is always available whereas it must be generated by revolving the magneto armature if attempt is made to start on the magneto. Some forms of magneto, notably those of the true high tension type, generate current enough to ignite the gas even if the armature is turned slowly. Magnetos of the transformer coil type do not generate current enough at low speeds provided by hand cranking to furnish positive ignition. Most car manufacturers, therefore, advise starting on the battery.

Q. Where should speed change gear lever be, and why?

A. The gear shifting lever should be in neutral position, as shown at Fig. 247-B, because if it is in one of the speed positions so that a pair of gears are meshed it will not be possible to turn the engine without moving the car. If the engine is a type that is easily started it may pick up its explosions quick enough so the car will move as soon as the engine starts.

Q. Why should spark lever be retarded?

A. The spark lever should be placed in the retard position, as shown at Fig. 247-C, because an advanced or early spark will pro-

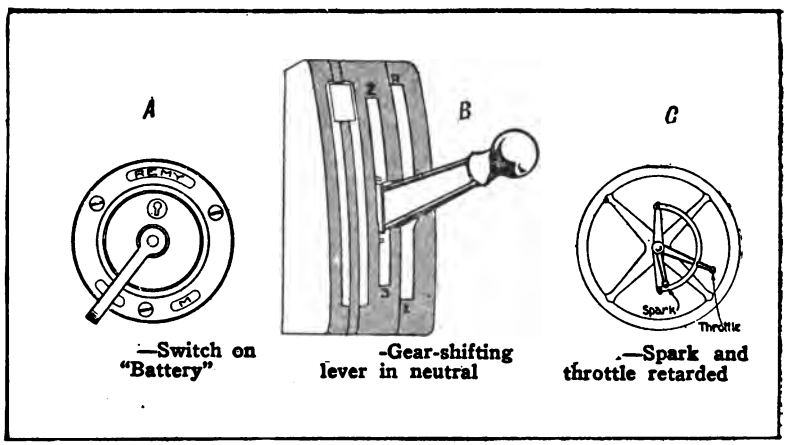


Fig. 247.—Position of Switch, Gear Shift and Motor Control Levers on Overland Car Before Starting Engine.

duce a back kick or preignition in the cylinder that will tend to reverse the crankshaft rotation and bring the starting crank forcibly in contact with the operator's arm or wrist.

Q. How should throttle control lever be placed?

A. The throttle control lever should be partially advanced in order that a supply of gas be drawn into the motor cylinder as the engine is cranked over by hand. The position of the throttle lever relative to that of the spark control on the Overland car is outlined at Fig. 247-C.

Q. How should motor be cranked?

A. The method of cranking the motor properly is outlined at Fig. 248. In the first place the starting handle should be grasped in the hand as indicated in the inset *A* because if held in this manner it will be pulled out of the hand if the motor should back fire due to an advanced spark lever and early explosion. In cranking the motor the starting handle should always be pulled up with a quick, sharp movement. One should never push down on a starting handle, because when one pulls if there is a reversal of crankshaft motion

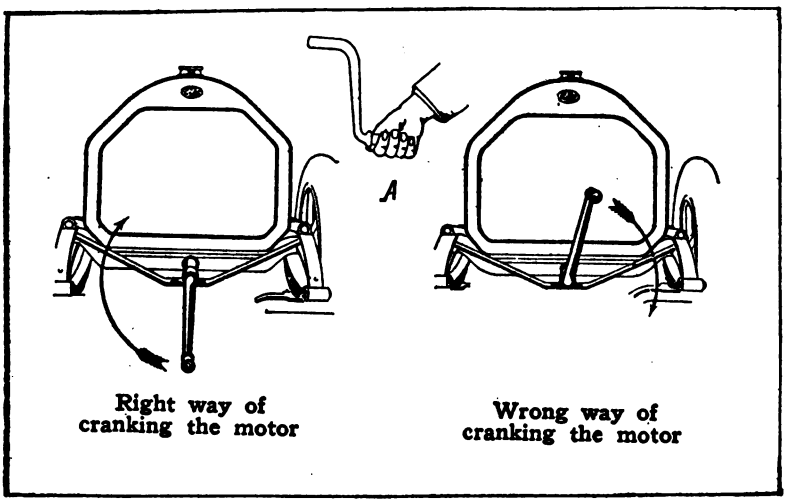


Fig. 248.—Proper Method of Grasping Hand Starting Crank in Order to Avoid Injury Due to Backfire.

the starting crank will be pulled out of the hand, whereas if one pushes down a back kick is apt to injure the arm or wrist.

Q. Describe process of "tickling" carburetor and explain why this is sometimes necessary.

A. After a carburetor has been standing for a time a certain portion of the liquid in the float bowl is apt to evaporate or leak out and the level of fuel will be so low in the standpipe that gasoline will not be drawn out to start the motor. In order to insure having

sufficient gasoline in the mixing chamber it is customary to depress the float several times with a small priming pin or plunger protruding through the float bowl cover. This process is commonly called "tickling" the carburetor and causes a portion of the gasoline to overflow the standpipe so when the air is sucked through the mixing chamber it picks up some of the liquid fuel and a rich mixture is produced that makes starting easy. Depressing this pin is sometimes called "priming" the carburetor.

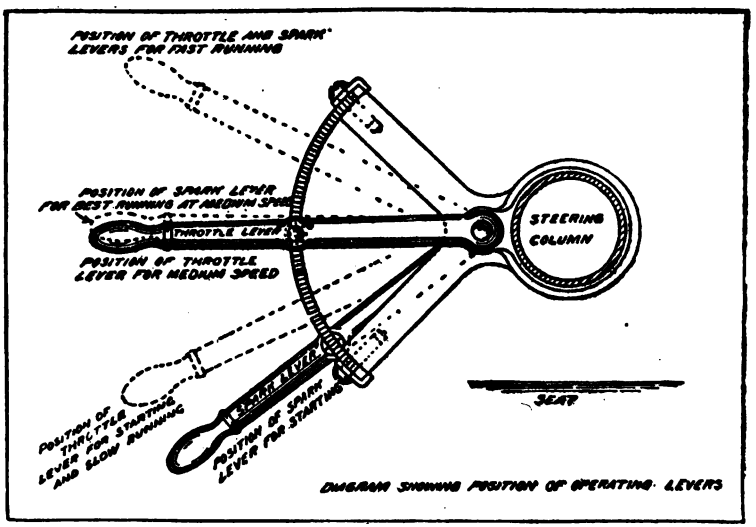

POSITION OF THROTTLE AND SPARK LEVERS FOR FAST RUNNING
POSITION OF SPARK LEVER FOR BEST RUNNING AT MEDIUM SPEED
THROTTLE LEVER
POSITION OF THROTTLE LEVER FOR MEDIUM SPEED
STEERING COLUMN
SEAT
POSITION OF THROTTLE LEVER FOR STARTING AND SLOW RUNNING
POSITION OF SPARK LEVER FOR STARTING
DIAGRAM SHOWING POSITION OF OPERATING LEVERS

Fig. 249.—Showing Various Positions of Motor Control Levers for Different Engine Speeds.

Q. What is another method of priming the engine with fuel?

A. With most types of motors, starting will be considerably facilitated on a cold morning or after the car has been standing for a time if gasoline is introduced directly into the cylinders through the priming cocks or compression relief cocks on the cylinder heads.

Q. What is the first step after the engine starts, and why is it necessary?

A. As soon as the engine starts, the throttle lever should be

pulled back until the throttle is almost closed in order to prevent the engine "racing."

Q. What is the objection to engine racing?

A. If a motor runs at high speeds while the car is not in motion it will be subjected to unnecessary wear and the car will vibrate unduly.

Q. How is engine speed controlled?

A. The approved method of controlling engine speed is by spark

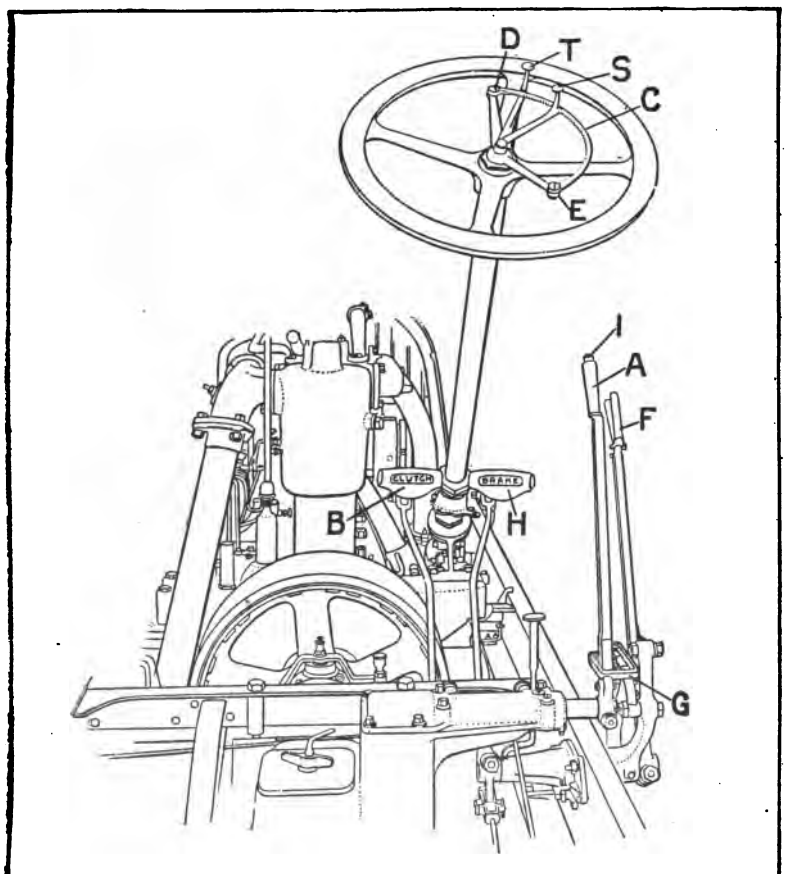


Fig. 250.—Motor and Car Control Group of Pope-Hartford Car.

and throttle levers, as shown at Figs. 247-C, 249, and 250. In most cars the spark and throttle levers are carried above the steering wheel where they may be easily reached, though sometimes they are mounted on the steering column, as shown at Fig. 249. As a rule, advancing the spark and giving the engine more gas by moving the throttle lever will accelerate motor speed, while retarding the spark and cutting down the supply of gas will slow the engine down. The various positions of the spark and throttle levers of the Pierce-Arrow car for starting, slow, medium and fast running are indicated at Fig. 249.

Q. Describe an automatic engine stop to prevent excessive speed.

A. Some forms of engines are provided with a governor connected with the throttle in such a way that when the engine speed exceeds a certain predetermined point the throttle will be closed by the governor and the engine speed will slacken automatically.

Q. Outline common method of cutting out governor action.

A. In cars where a governor is fitted on the engine the gas lever or a foot accelerator may be used to open the throttle independently of the governor so that this member will only be operative when the throttle lever or accelerator pedal is set for low or medium speeds.

Q. Why should spark be advanced after engine is started?

A. The spark lever should be moved from the retard position as soon as the engine is started in order to bring the ignition point so the spark takes place just when the piston reaches the end of its compression stroke instead of after it has started to go down on the power stroke. Continuous operation with lever in retarded position will mean overheating and loss of engine efficiency.

Q. What happens if spark lever is too far advanced?

A. If the engine is run with the spark lever advanced too much, the charges will explode before the piston reaches the end of its compression stroke and this preignition, or early explosion, will impose stresses on the motor bearings and will produce a pronounced knocking sound because it tends to oppose piston movement.

Q. What is the best position for spark lever under average running conditions?

A. The spark lever can be placed to best advantage at that point on the segment which corresponds to ignition when the piston reaches the end of the compression stroke, because this condition is one favorable to efficient engine action and makes possible very flexible control by throttle lever alone. In some cars using magneto ignition no provision is made for advancing or retarding the time of the spark which is set so it occurs slightly in advance of top center or when the piston has just compacted a charge of gas and is ready to descend on its power stroke. In cars using this system of control the engine speed is regulated entirely by the throttle lever or accelerator pedal.

Q. What should be done if any unusual noises materialize after engine is started?

A. If any unusual sounds are heard after the engine is started the operator should immediately stop the motor and investigate the cause of the noise. Sometimes considerable damage may be done to the mechanism by a loose or broken part if the engine is kept running when a defective condition has made itself known.

NOTE.—For further information on Engine Control see "The Modern Gasoline Automobile."—By Page

LESSON TWENTY-SEVEN

METHODS OF SPEED CHANGING OUTLINED

Q. Name the principal types of speed changing systems.

A. Speed changes may be effected by means of friction, planetary, sliding gear, and individual clutch gearing.

Q. Which are the simplest types to control?

A. The friction and planetary gearing are the easiest operated by the novice, though the individual clutch and selective sliding gear are handled just as easily by the more experienced motorist.

Q. What is the feature of the planetary gear set?

A. The important feature of an epicyclic or planetary gear set is that the speed reduction gears are always in mesh and that any speed may be obtained instantly by a simple movement which tightens a friction band or clutch acting only for the speed selected. As the gears are always in mesh and as the operation of obtaining a speed and applying a clutch is simultaneous, there is no danger of stripping gears or of doing other damage to the transmission.

Q. Name principal planetary gear car and describe controlling system.

A. Practically the only planetary gear car now on the market, but one that is sold in very large quantities, is the Ford Model T. The control system of this is shown at Fig. 251. The spark and throttle control are on the steering post under the wheel which is located at the left side of the car. The lever at the outside is for the spark advance while that on the right is the throttle lever controlling the gas supply. A single hand lever, which combines the function of an emergency brake actuator and high speed clutch release, is provided on the left side of the car. Three pedals are used, the one at the extreme left engaging the low speed when pushed forward and allowing the direct drive clutch which is spring engaged

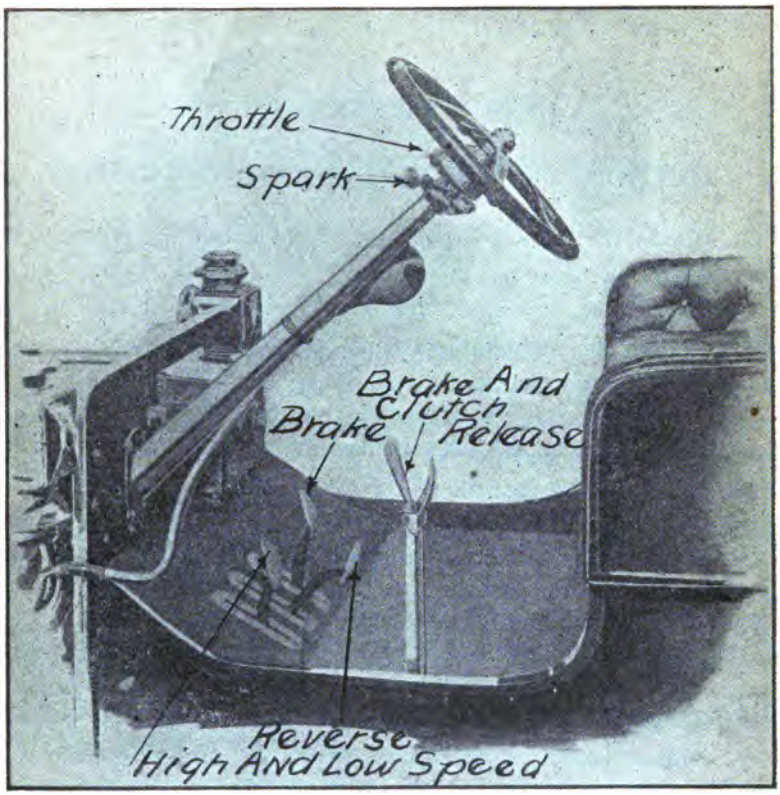


Fig. 251.—Control System of Ford Model T Car Which Uses Planetary Change Speed Gearset.

to come into action if allowed to drop to its rearmost position. When the emergency brake lever is applied the high and low speed pedal is in a neutral position. The middle pedal engages the reverse ratio when pressed forward, while that at the extreme right is a foot brake acting on the gearset.

Q. Describe simplest form of planetary control system.

A. The simplest form of planetary gear control system is that by which a single lever convenient to the operator's hand is used to engage all speeds. The lever has five positions, three of which

bring the gearset into operation, while the other two are neutral points in order to prevent passing from one speed to another too quickly. As generally arranged, if one brings the lever to its extreme rear position the reverse motion will be secured. Just forward of this point is a neutral position from which the lever may be brought into slow speed by pushing forward. If the motion of the lever is continued the second neutral point is passed and when the extreme forward position is reached the high speed is engaged. It will be seen that there are two neutral points, one between the low and reverse, the other between the low and high speeds. The lever may be placed in either neutral point when stopping the car, though it is preferable to place it between the low and reverse instead of between the high and low when stopping, as the car may then be moved either forward or backward, as conditions dictate.

Q. How are low speed and reverse ratios obtained in planetary gearset?

A. The low speed and reverse ratios are secured by tightening brake bands around the drum or case in which the reduction gears are carried.

Q. How is direct drive obtained?

A. Direct drive is obtained by means of a friction clutch of either the cone or multiple disc type, which locks the entire gearset assembly together so that the gearing does not revolve on its own axis but around the driving shaft center line so that the drive is obtained without any reduction in ratio except that existing between the bevel pinion and ring gear at the rear axle.

Q. How are speed changes obtained with friction drive?

A. Speed changes of friction drive cars are obtained by sliding the driven disk across the face of the driving member by means of a suitable handle or disk shift lever at the side of the car.

Q. Describe typical friction drive car control system.

A. The control system of a friction driven automobile is simple as it consists of the usual spark and throttle control levers on the steering post, a hand lever to obtain the varying speed ratios and

two pedals. One of the pedals is used to release and apply the power by moving the friction members from or toward each other. This pedal is provided with a ratchet lock so it may be retained in position desired by the operator. The other pedal is a brake applying member. Before the hand lever can be moved to shift the friction disk it is necessary to break the driving connection between them by releasing the pressure at the pedal. Changes of speed are obtained progressively, the usual arrangement being to engage the discs for reverse motion when the lever is toward the rear of the car and to obtain high forward drive ratios as the lever is pushed toward the front of the car. The degree of pressure to

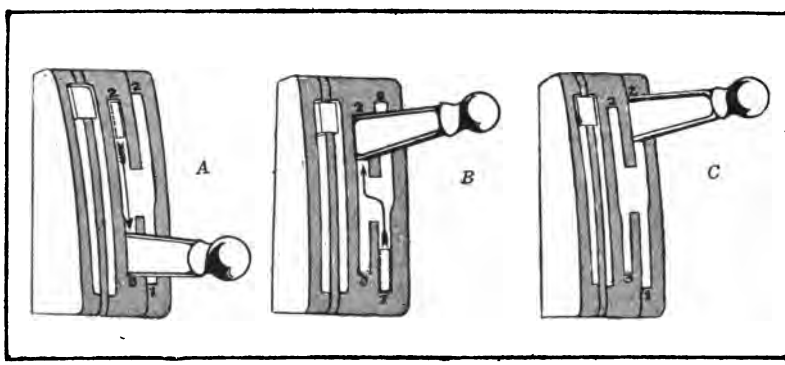


Fig. 252.—Selective Gear Quadrants.

be applied at the friction pedal depends upon the character of the road surfaces. On good roads but little pressure is needed to secure positive driving, but as road conditions become more severe a greater degree of frictional adhesion is desired so more pressure must be applied by the pedal.

Q. What two methods of sliding gearset control are used?

A. Sliding gearsets may be controlled either by the progressive or selective system.

Q. What is a progressive gearshift, and what are its disadvantages?

A. The progressive gearshift is the type where the hand lever must be pushed from one extreme of a segment to the other to obtain varying speed ratios which are progressive in their application. This sector is usually provided with five notches if used on a three speed and reverse gearset. The rearmost notch is the reverse position. The next one working toward the front of the car is a neutral point and then the low speed, intermediate and direct drive

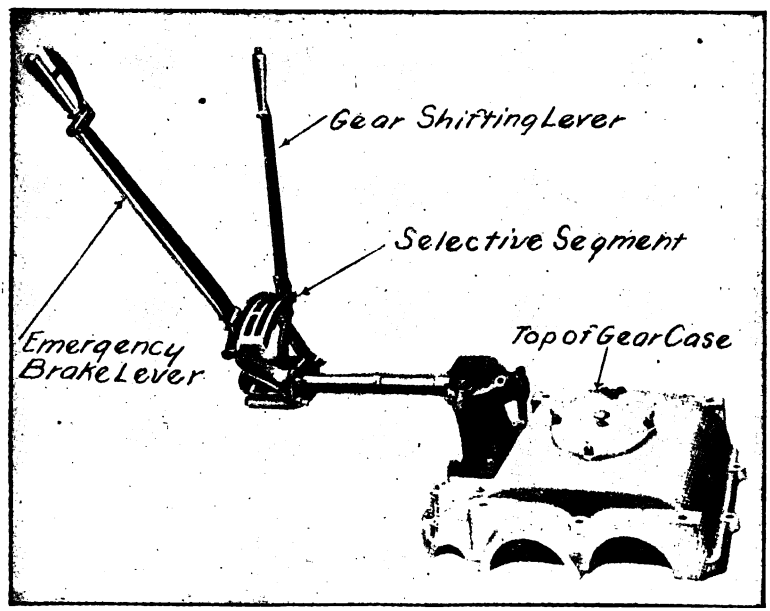


Fig. 253.—Gear Shifting and Emergency Brake Lever Assembly Attached to Selective Gearset Case.

positions follow in the order named. The disadvantage of this system is that if the lever is in the reverse position and it is desired to engage the intermediate or high speed, it is necessary to first pass through the low speed before the higher ratios can be secured. This gear control is not very widely used as it is slow in action and requires careful gear shifting in order to avoid injuring the gear teeth.

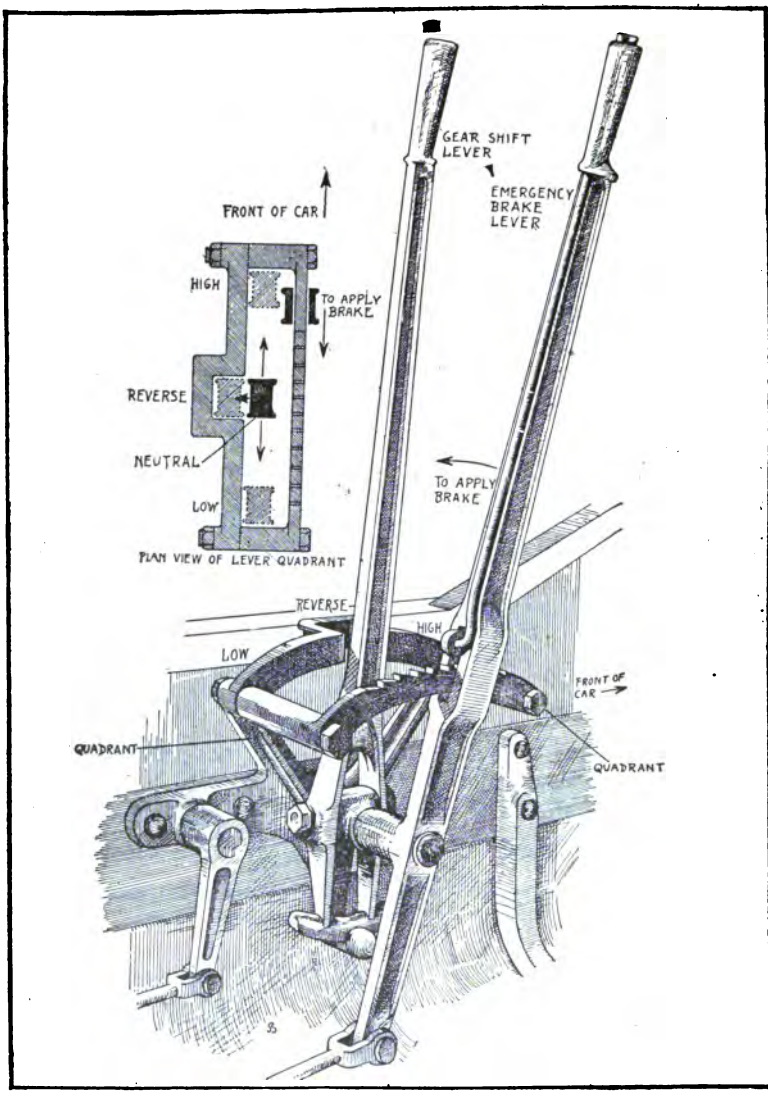


Fig. 254.—Simple Gearshift System for Two Speed and Reverse Gearset Used Early Hupmobile Cars.

Q. Describe selective system, and give advantages.

A. The selective system uses but one hand lever, as shown in illustrations Figs. 252 to 256 inclusive, to obtain varying speed ratios, but this works in an H slot segment member outlined at Figs. 252 and 253 which makes it possible to go from the neutral position into any gear ratio desired or from one ratio to the other without engaging any other gears than those desired. This is accomplished by providing a lever capable of side motion, as well as fore-and-aft movement. The manner in which the lever can be brought from second speed to direct drive is clearly outlined at *A*, Fig. 252, from first speed to second in the manner indicated at *B* and into the reverse position as shown at *C*. When the lever is placed in the passage separating the two slots in the segment it is at its neutral position.

Q. What are the essentials of a sliding gear control system?

A. A simple selective sliding gear control system and the position of the levers to obtain various speed ratios on a simple two speed gear set is outlined at Fig. 254. When three speeds are provided, as shown at Fig. 255, the gated segment provides five possible positions for the gear shifting lever. The control system outlined, which is that of the Overland car, is typical of modern practice and consists of the usual motor control levers carried at the top of the steering post, two hand levers, one for gear shifting and the other for emergency brake actuation and four foot-operated pedals, two of which are used in controlling the car directly while the accelerator button controls the car velocity by varying the engine speeds. One of the large foot levers is a brake pedal, the other is a clutch pedal. The accelerator or small button in the floor board acts on the throttle of the carburetor while the muffler cut-out is employed to open a valve in the exhaust pipe and enable the gases to be discharged directly into the air instead of passing through the muffler. The control system of the Rambler car, which is somewhat similar to that previously described except for the location of the hand levers, is clearly outlined at Fig. 256.

Q. Outline function of clutch pedal.

A. The clutch pedal, which is usually placed so that it can be

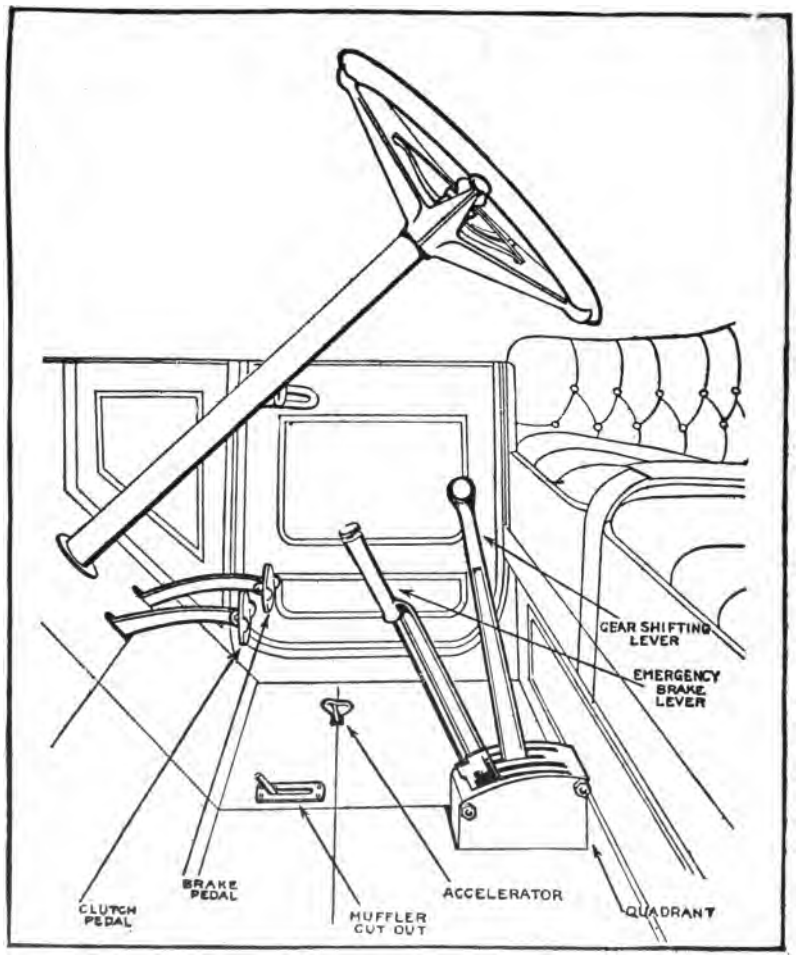


Fig. 255.—Complete System of Overland Cars.

operated by the left foot on most cars and which is clearly depicted at Fig. 257, is utilized to disconnect the engine power from the gearset whenever it is desired to shift the speed changing lever. The clutch pedal also permits the driver to release the engine power from the rear wheels whenever it is desired to slacken speed and also provides

for smooth clutch engagement in starting the car from a standstill if properly actuated.

Q. Describe method of starting sliding gear car.

A. After the engine has been started in the manner indicated in preceding lessons, the first step is to depress the clutch pedal, then accelerate the engine speed slightly and after pushing the change speed lever in low gear position the clutch pedal is gradually

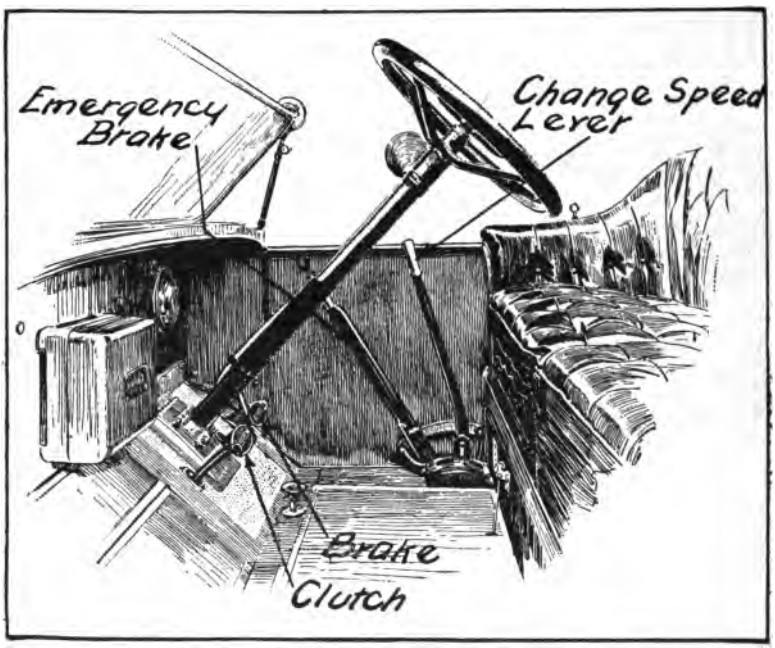


Fig. 256.—Control System of Rambler Automobile.

released so the engine power is transmitted to the rear wheels. After the car has attained a certain momentum which it does in from ten to twenty yards the clutch pedal is again depressed and if the car is operated on a level road the gearshift lever may be pushed into direct drive position and the clutch again re-engaged gradually. If on a slight up-grade, however, it will be best to pass into the intermediate or second speed from the low speed before

going into the highest ratio. Care should be taken always to depress clutch pedals before shifting the gear lever and also to accelerate engine before engaging the clutch.

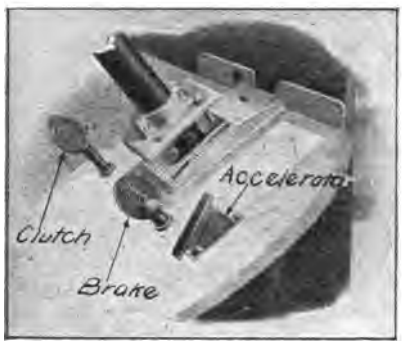


Fig. 257.—Showing Clutch, Brake and Accelerator Pedals of Rambler Automobile.

Q. Why must engine be accelerated before clutch is engaged?

A. If the engine speed is not accelerated before clutch is engaged it will not deliver sufficient power to start the car and as soon as the clutch takes hold the resistance will be too great for the motor which will become "stalled" or stop. If the engine is speeded up it will develop more power than is needed to start the car and unless the clutch is very suddenly engaged it is not likely to stop.

Q. What would happen if gears were shifted without releasing clutch?

A. If attempt was made to shift the gears in a sliding gearset without first releasing the master clutch the effect of bringing two rotating gears into engagement would be to strip the teeth of the gears on account of the shearing action between them when the edges of one set of hard teeth engage the corresponding side of the other set. If the clutch is released, one set of gears stops and the other gear which is moving if the car is in motion can engage the gear which is not turning without injuring the teeth of either member.

Q. Describe some standard selective quadrants.

A. There is considerable difference of opinion among motor car designers regarding the arrangement of the selective quadrants and the positions of the lever for obtaining various speeds. In some cars the reverse position may be at the front end of the sector, whereas in others it is in the more logical place or rear end. The various positions of the lever for obtaining different speed ratios on typical standard cars are clearly outlined at Fig. 258. The letter

R indicates the reverse position; *N* a neutral point, while the lowest speed is indicated by *I* and the others as 2, 3 and 4, the ratio becoming higher as the value of the indicating numeral advances.

The sector shown at *A* is used on Stoddard, Stearns, Mitchell, Jackson, Overland, Regal, Speedwell, Kissel, Courier, Hudson, Thomas M. Pierce-Racine, Marmon, Apperson, Mathewson Six, Cadillac, E. M. F., Elmore, Velie, Chalmers, and Reo. This is the most popular form of segment and has been widely used. The type at *B* which is a reversal of the former, inasmuch as the lowest and reverse speed positions are in the outer slot instead of the inner, is used on the Premier, Buick, Pope-Hartford, Black Crow, Haynes,

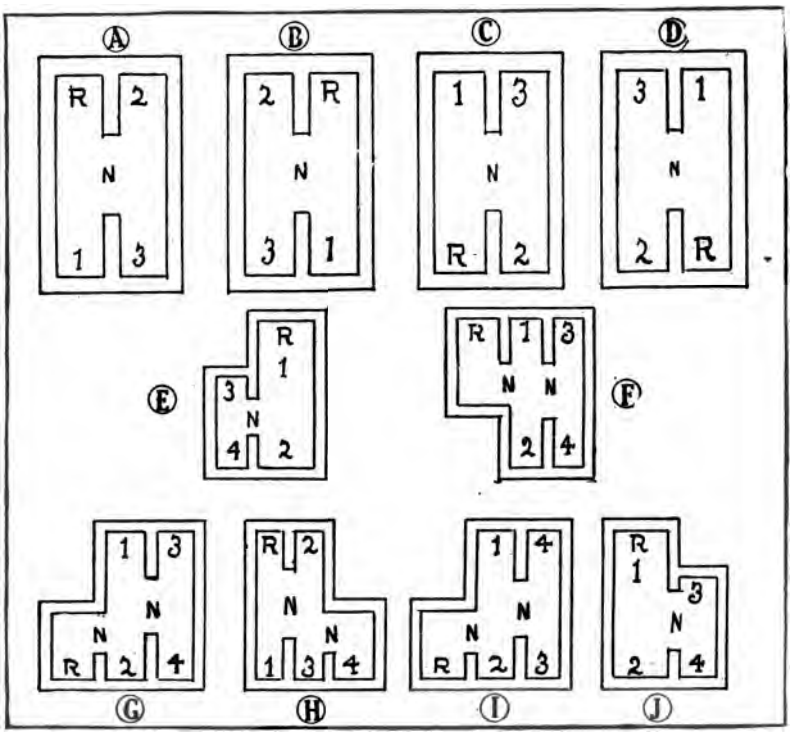


Fig. 258.—Selective Gearshift Quadrants That Have Received General Application.

and Fal cars. The form shown at *C* is considered by many engineers to be a more logical one as the reverse position is at the rear of the segment and the two most commonly used forward speeds are at the front end. This has been used on the Rambler, Interstate, and National cars. The type outlined at *D* is a reversal of the form shown at *C* and has been used on the Corbin and Columbia automobiles.

The four speed segments are shown in the following figures and are used on cars as follows: type *E* is used on the Locomobile, *F* on the Peerless, *G* on the Apperson, *H* on the Winton, *L* on the Palmer-Singer, and *J* on the Pierce Arrow. Contrasted to the three speed and reverse segments with the five positions for the lever the four speed segments have six or seven positions, some having an individual place for each speed, while others have a common shift member and obtain the reverse, first and second speeds progressively with but one neutral point.

Q. How are speed changes effected when individual clutch gear is fitted?

A. When an individual clutch gearset having gears always in mesh but employing positive jaw clutches in the gearset is used in connection with a master clutch at the engine, varying speed ratios are usually obtained by a selective control just as in a sliding gearset, and care must be taken to operate the master clutch every time a different speed ratio is desired.

Q. What is the Vulcan electric gear shift, and how does it operate?

A. A new system of gear shifting has been recently developed which depends on the use of electric current to shift the gears instead of the usual hand lever. The steering wheel is shown at Fig. 258-A with the various speed changing buttons let into one of the wheel spokes. The operation of shifting a gear is very simple, consisting merely of depressing the clutch pedal and pressing down on the switch button marked with the gear ratio desired. The system is not complicated, the gears being controlled by solenoid coils, one being used for each forward speed and one for reverse. Two switches are utilized between the battery and the coils, a knife

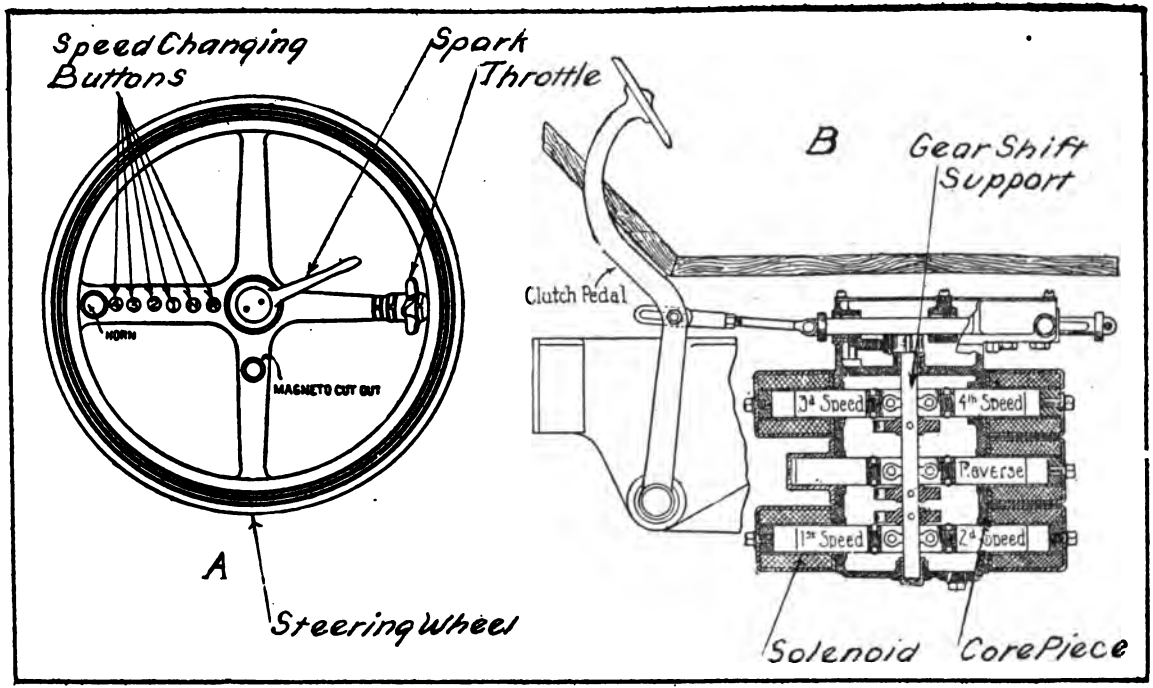


Fig. 258A.—View of the Steering Wheel of the S. C. V. Automobile Showing Speed Changing Buttons at A. Solenoids Employed in Shifting Gears and Clutch Pedal Operated Switch of Vulcan Electric Gear Shift System at B.

switch controlled by the clutch pedal and a push button located on the steering wheel. All changes of gears are controlled by the knife switch and the push buttons on steering wheel merely arrange the circuit for the particular speed desired. A glance at the drawing shows that the clutch pedal moves through a link during the first part of its motion and during the remainder picks up the link and carries it along with it. Thus the first movement is the regular operation of the clutch, but a continued operation of the clutch lever actuates the knife switch.

Current flows from the battery through the solenoid coil and pulls a plunger against a magnet with a force which is given as 150 pounds. This energy is transmitted through an arm to the gear-shifting fork and gear in exactly the same manner as if the gears were operated with a hand lever. The plungers in the illustration are shown in a neutral position. When the button is pressed on the control member, current passes through the coils around the plungers, drawing them against the magnet. It is said that the current required to make the shift is about 17 amperes, and it is claimed, further, that three hundred speed changes may be made with less current consumption than is required in starting the motor with an electric starting device.

An advantage claimed for this electric gear shift is that the gears cannot be stripped, for the reason that the clutch must be disengaged before a shift can be made and the gears are always in neutral before the coils can accomplish the change. Furthermore, no two speeds can be utilized at the same time because each speed is governed independently of the others, and an interlocking device prevents the operator from using any two buttons at one time, even if he should make a mistake or be careless.

The box which contains the switches and solenoid coils is mounted at the side of the gear box, and it is said that the device adds only 46 pounds to the weight of the chassis. On the S. G. V. car the control buttons are mounted in a neat aluminum box on the steering wheel, one for each speed, and one for a neutral member. In operation the system is very simple. If, for instance, the fourth speed button is pushed down and the clutch is thrown out and then re-engaged, the car will remain in fourth speed. When driving

in traffic on the third speed the driver may set the second speed button and by depressing the clutch pedal fully will automatically shift into second speed. In a similar manner all other changes may be made. The driver need not lift his hand from the wheel in order to accomplish any change in the gears. Those who have witnessed the operation of this device state that the system is quiet, the only noise being a slight click as the gears engage when changed. This system is also used on the Haynes 1914 automobiles and several other types.

NOTE.—For complete discussion of all standard gear shifting systems see "The Modern Gasoline Automobile."—By Pagé.

LESSON TWENTY-EIGHT

UTILITY OF BRAKES AND THEIR USES

Q. What is the purpose of the braking system?

A. The brakes of an automobile or any other vehicle are used to arrest its motion when desired.

Q. How do motor car brakes differ from those used on wagons?

A. The shoe brake, which consists of a friction block bearing against the wheel tire, is generally used on wagons and in railway practice. Automobile brakes act on special drums attached to some part of the power transmission system and not on the wheel tire.

Q. Why is the shoe and tire brake undesirable on automobiles?

A. If the automobile, which is a self-propelled vehicle, and which can be stopped only by application of the brakes, utilized shoes bearing against the wheel tires the constant application of the braking member would result in rapid depreciation of the tires which deteriorate rapidly enough from normal usage.

Q. What forms of brakes are used on motor car chasses?

A. Brakes employed in motor cars are of the band or shoe form and may be applied to the exterior or interior of the brake drums. The brake shown at Fig. 259 is an internal form in which two brake shoes are spread by a cam until they engage the inner surface of a steel brake drum usually attached to the propeller shaft or to the rear wheel hub. The brake outlined at Fig. 260 is a constricting form applied to the outer periphery of the brake drum and which arrests motion of the drum by binding a band tightly around it. Sometimes the cast shoes of the internal brake are replaced by a

band of steel faced with some frictional material such as Raybestos and in some cars the external brake is composed of a pair of cast shoes hinged to clamp the brake drum between them when applied.

Q. Where are brakes applied?

A. The braking members of modern automobiles are generally attached to the rear axle and are applied directly against drums carried by the wheel hubs. A typical assembly is shown at Fig. 261 with the drum removed in order to outline clearly the construc-

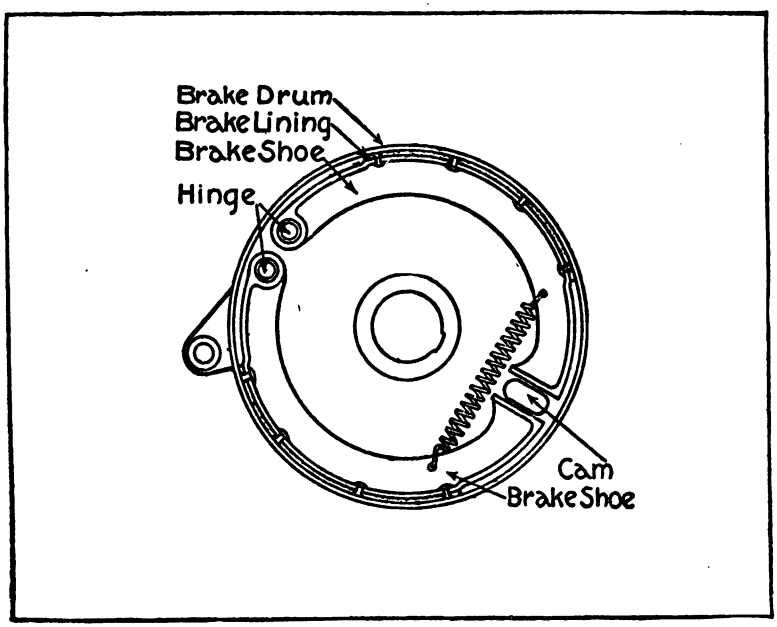


Fig. 259.—Internal Expanding or Shoe Brake.

tion of the brake members. The internal brake which is cam expanded is composed of a steel band faced with Raybestos or other woven asbestos fabric, the action of the cam being to spread out the brake against the inner periphery of the brake drums. The external brake band is made of lighter material than the internal member and is constricted around the brake drum by a simple bell crank

lever. Both inner and outer brakes are supported by spring members in order to keep them out of engagement with the brake drum unless applied and to prevent rattle.

Q. Can brakes be fitted to other parts of a car besides the wheels?

A. In some forms of pleasure cars the regular or service brake is applied on a drum at the drive end of the transmission to which the driving shaft is attached as shown at Fig. 262, while in some

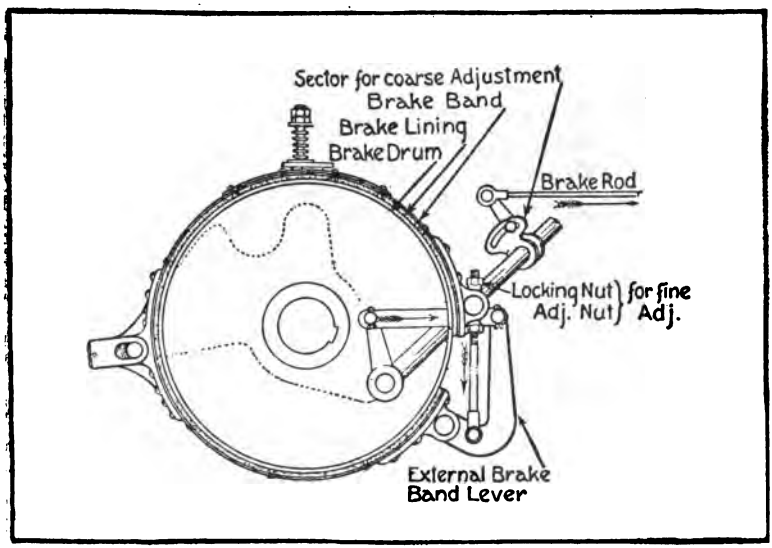


Fig. 260.—External Constricting Band Brake.

motor trucks, in addition to the rear wheel location a service brake may be attached to drums that are in direct mechanical connection with the driving sprockets on the countershaft. A brake of this nature is shown at Fig. 263 and is used as a service brake while the emergency braking effect is obtained by a pair of shoes expanded by a cam.

Q. What are the advantages of countershaft and driving shaft brakes?

A. An important advantage gained by applying a brake to a

transmission member revolving at higher speed than the rear wheels is that a smaller brake can be used to retard the vehicle on account of the multiplication of power obtained by the difference in ratio between the driving and driven sprockets or the driving pinion and driven gear. This is considered by some designers to be a construc-

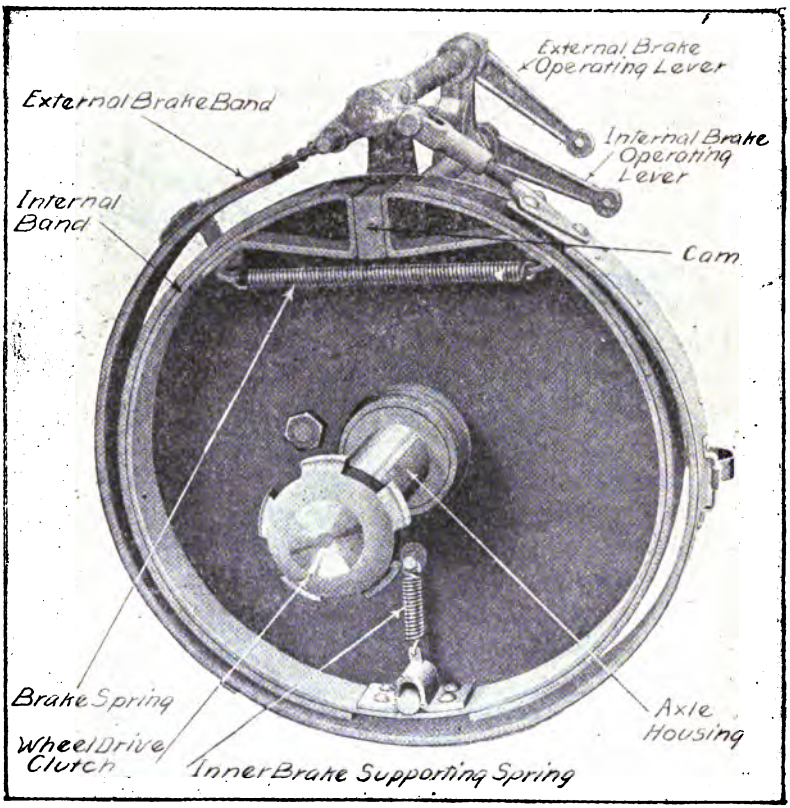


Fig. 261.—Double Brake Assembly Intended for Rear Wheel Hub Drum.

tion subject to criticism inasmuch as it is contended that the driving elements are subjected to considerable stress by using them for both driving and braking purposes that they would not be called upon to take if used only for driving purposes.

Q. Discuss features of internal brake location.

A. An important advantage of the internal brake is that it is entirely enclosed and protected and that it can be firmly attached to the member taking the braking torque. As it is installed inside of the brake-drum it is liable to be affected by accumulations of lubricant leaking out from the axle housing. It is also difficult of access for repairs or adjustment, so most designers endeavor to provide a construction that will not need frequent adjustment, and then use this brake for emergency purposes so that it is not called

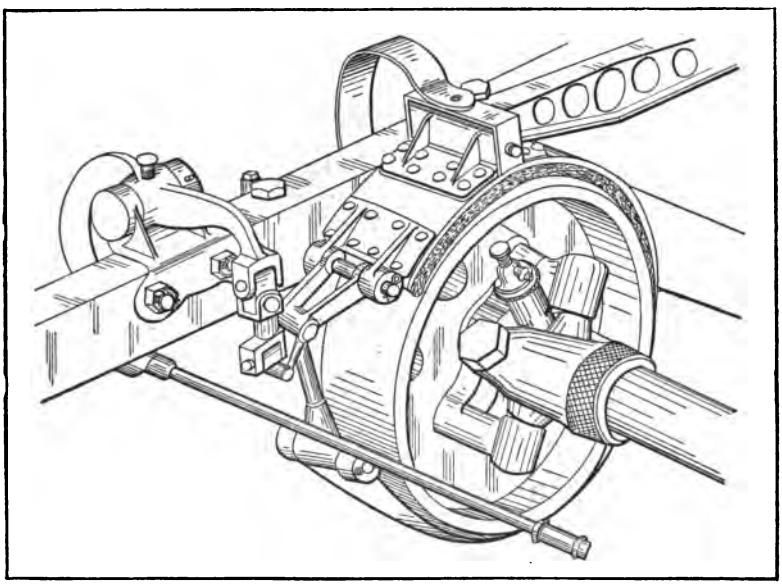


Fig. 262.—Typical Propeller Shaft Brake of External Constricting Band Form.

on as often as the regular service brake which is usually of the external band pattern.

Q. Discuss disadvantages and advantages of external brakes.

A. Most of the external brakes have a disadvantage in that they are apt to rattle against the brake drums and also that they detract from the neat appearance of the wheel owing to their unsymmetrical form. Brakes of this nature are very efficient, however,

and they may be easily adjusted or removed if it is desired to replace the brake lining without disturbing the wheel, as would be necessary if the internal brakes demanded attention.

Q. What materials are usually employed in brake construction?

A. Materials to be used in brake construction must have strength, endurance, and possess a high degree of friction. The materials ordinarily used are metals where strength is desired and various fibrous substances having a high degree of frictional adhesion for brake linings and facings.

Q. What are brake drums made of?

A. Brake drums are commonly made of steel, those on the lighter cars are formed by stamping the drums from the sheet under powerful presses while on heavy vehicles steel castings are employed. With the ordinary form of pressed steel brake drum the surfaces are sufficiently smooth and true to size so no machining is necessary, but the castings must be faced off in order to obtain a smooth surface against which the brake band can bear.

Q. What are brake shoes made of?

A. Brake shoes may be made of steel, bronze, or malleable iron castings on the larger types and of drop forgings in the smaller sizes.

Q. What materials are used to increase friction of brakes?

A. Among the materials used to promote greater frictional adhesion may be mentioned camels' hair belting, woven wire and asbestos fabrics sold under the trade names of Raybestos, Multibestos, etc., and cork.

Q. How is brake lining attached to band or shoe?

A. Brake linings are attached to the brake bands or shoes by means of copper rivets which are countersunk in the friction material and tightly riveted over at the inner side of the brake band.

Q. How are cork inserts used?

A. Cork is employed in the form of inserts which is compressed into suitable holes drilled to receive them in the brake shoe castings which are generally of bronze or cast malleable iron when the

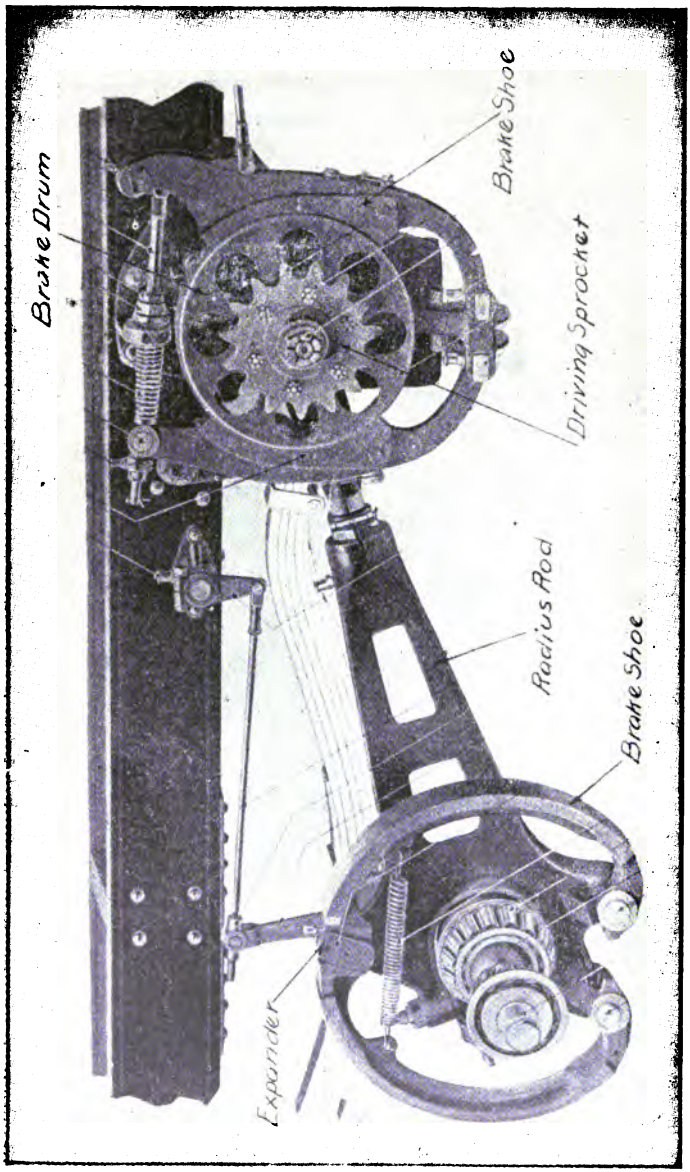


Fig. 263.—Countershaft Brake of the Caliper Type Used on Packard Motor Trucks.

cork is employed and of special form having pockets to receive the frictional material. The use of cork provides for a greater degree of friction and enables the brake to work more efficiently if oil is present between the surfaces and also promotes gradual brake application.

Q. What must a brake do to be efficient?

A. In order to have the vehicle under perfect control a brake must be able to lock the driving wheels in a manner that will entirely prevent them from rotating, and it should be capable of performing this function with minimum exertion on the part of the operator.

Q. Are quick acting brakes desirable?

A. Quick acting brakes, which will stop the wheel rotation too soon, are not desirable because these make for rapid tire depreciation. Most brakes are designed so they can be applied gradually.

Q. How are brakes operated?

A. The service brakes, which are generally of the external form, re operated by a pedal adjacent to the clutch pedal, while the emergency brakes, which are usually of the internal type, are brought into action by a hand lever mounted near the gearshift member and carried on a quadrant and provided with a latch so that it can be locked in position.

Q. What is a clutch and brake interlock?

A. In some cars a single pedal is used to control both clutching and braking functions. The pedal is only pushed about half way of its available travel to release the clutch quickly and from that point to the end of its movement it will apply the service brakes. Obviously, it is not possible to apply the brake without first releasing the clutch. In some other forms of cars the brake pedal is connected with a mechanical leverage so that it cannot be moved without throwing out the clutch, though the clutch pedal may be moved without applying the brake. The clutch and brake interlock is sometimes obtained by the emergency brake lever and this construction is preferred to the foot brake and clutch interlock.

LESSON TWENTY-NINE

GENERAL DRIVING INSTRUCTIONS

Q. What is the general road rule of this country?

A. When approaching a vehicle coming from the opposite direction the rule is to keep to the right of the road and to pass all vehicles going in the same direction on the left.

Q. How does this differ from the road rule of Europe?

A. The road rules of most of the European countries are just the reverse to those in vogue in America as the vehicle must keep to the left of the road and pass conveyances going in the same direction on the right.

Q. What is the logical position for steering wheel and control levers, and why?

A. In order to conform to the road rules of this country the logical position of the steering wheel is at the left side of the car and the control levers should either be at the extreme left or in the center of the car.

Q. Why is right hand drive so general in this country?

A. As most of the American automobiles have been derived and adapted from European designs the right hand location of the steering wheel has been preserved with other features and while this is logical for the road rules obtaining in foreign countries it is not so well adapted to American conditions as the left hand drive.

Q. Why is central location of control levers desirable when steering wheel is placed on left hand side?

A. As most motorists are familiar with cars in which the speed changing is performed with the right hand and as most people use their right hand to better advantage than the left, placing the control levers at the center of the car enables one to handle the steering

wheel to advantage if this is at the left and at the same time the speed changing and emergency brake levers which are at the center of the car can be easily handled with the right hand which would also be used for this purpose on cars having right hand drive.

Q. What should a careful driver always have in mind?

A. A careful motorist will always have the safety of other users of the highway in mind which means that a car should be driven carefully and at moderate speeds so it is always fully under the control of the operator.

Q. Why is driving at high speed undesirable?

A. Driving an automobile at high rates of speed is not a desirable practice because the machinery is subjected to great stresses and the parts are very frequently overloaded if a car is driven near its maximum speed. The mechanism is subjected to more wear and the tires are more susceptible to derangement at high speed than at low and moderate speeds. When a motor vehicle is driven fast it will acquire considerable momentum and it will be very difficult to stop promptly in case this is desirable, and if a sudden stop is made the parts of the braking system and the general frame structure will receive a sudden shock that is liable to injure some parts.

Q. What is a safe speed on good road in thinly settled parts?

A. An automobile may be run at speeds ranging from 25 to 35 miles per hour under favorable conditions and still be under control.

Q. How do road conditions affect speed?

A. It is not desirable to drive a car at high speed over rough or wet roads nor is it safe to drive fast on a winding road having many curves or intersecting roads. If a car is driven at high speed over rough roads the various chassis parts will be subjected to considerable stress and the vibration resulting will prove very uncomfortable for the passengers.

Q. Why is careful driving in traffic imperative?

A. It is necessary to have a car always under perfect control when driving through cities or in settled communities because it

is often essential to make a quick stop and the ability to arrest the motion of the vehicle positively in a few feet may often be the means of averting an accident of serious moment.

Q. What is the danger of fast driving on wet roads?

A. The traction or frictional adhesion between the tires and wet road surfaces is very low compared to that over dry road surfaces, and as the mud or water acts as a lubricant the car is likely to skid if the brakes are applied, so that control becomes erratic.

Q. What parts of a car need special attention before starting on a trip?

A. Assuming that the power plant is all right, which condition can be readily determined as soon as the engine is started, the points that demand attention are the steering system, the tires and brakes. Special attention should be given to the various steering connections and the brakes should always be kept in proper adjustment on account of the important bearing these have on the safety of the car and its occupants.

Q. Describe operations necessary to make a gradual stop.

A. The first step in making a gradual stop with any car is to slow down the engine by cutting down the supply of gas, throw out the clutch when several yards away from the point where the stop is to be made and apply the service brake gradually until car speed is retarded to the proper point.

Q. Outline method of making an emergency stop.

A. The method of making an emergency or quick stop with a sliding gear car is clearly outlined at Fig. 264. The operator does not take time to slow down the engine but presses both pedals down and applies the emergency brake hand lever. By pushing both pedals at the same time the clutch is released and the service brake applied simultaneously and the braking effect is further augmented by the application of the emergency brake lever. One hand is kept on the steering wheel to steady the car.

Q. How should any car be started or stopped?

A. Any automobile must be started or stopped gradually in order to avoid shock and undue stress on the mechanism.

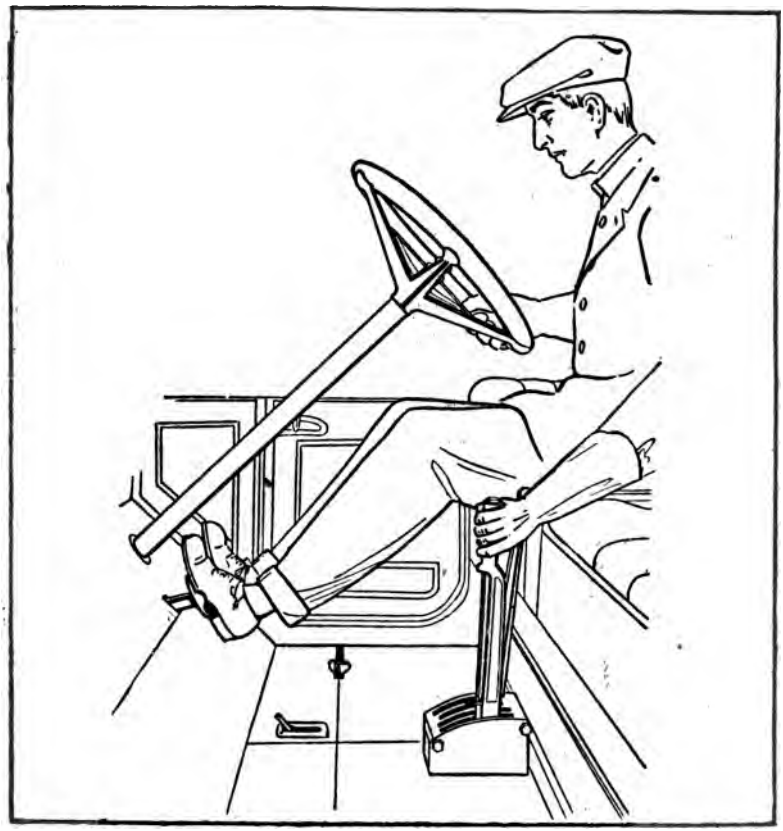


Fig. 264.—Showing Method of Making an Emergency Stop With Sliding Gear Control System.

Q. Is sudden acceleration of engine speed desirable?

A. It is just as important to increase the engine speed by gradual movement of the spark and throttle lever as it is to engage the clutch or apply brakes gradually.

Q. What is the normal position of spark lever on good roads, and under unfavorable conditions?

A. When running on good roads the spark lever should be advanced as much as possible without producing a knock in the engine and speed variations obtained by throttle or accelerator control.

On bad roads, when climbing a grade or under any other conditions that will cause the engine to slow up, the spark lever must be retarded to such a point that the engine will not knock.

Q. What is necessary before changing gears?

A. Before shifting the speed changing lever it is necessary to slow down the engine and to release the clutch by applying the pedal.

Q. What is the best method of negotiating a small strip of unfavorable highway, such as one covered with crushed stone?

A. The best method of passing over a short strip of unfavorable highway is to gather just sufficient momentum before reaching the obstructions so the clutch may be released and the car coast over the broken stone at a slow speed.

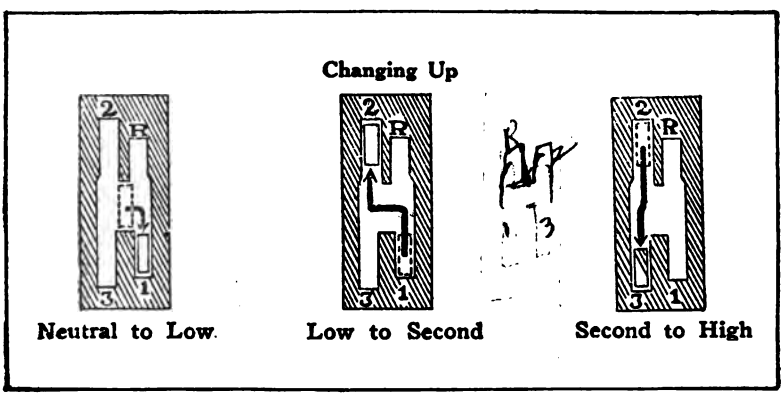


Fig. 265.—Method of Changing From Lower to Higher Speed Ratio With Selective System.

Q. Describe methods of driving a car on long stretches of poor road.

A. As it is not good practice to drive a car at high speed over unfavorable highways and as the road resistance may be such that the full power of the engine will be needed it is always well to throw the speed change lever in one of the lower gear positions and drive the car on either first or second speed depending upon the nature of the roadway.

Q. What should be done before passing another vehicle?

A. Sufficient warning, by means of the bulb or electric horn, should always be given before attempting to pass another vehicle. The car speed should always be slacked up in passing a pedestrian or a horse drawn conveyance and sufficient warning given in order to prevent confusion. If a horse is restive and appears frightened it is only common courtesy for the motorist to pull up to the side of the road and throttle the engine down low in order to prevent noise and avoid frightening the animal.

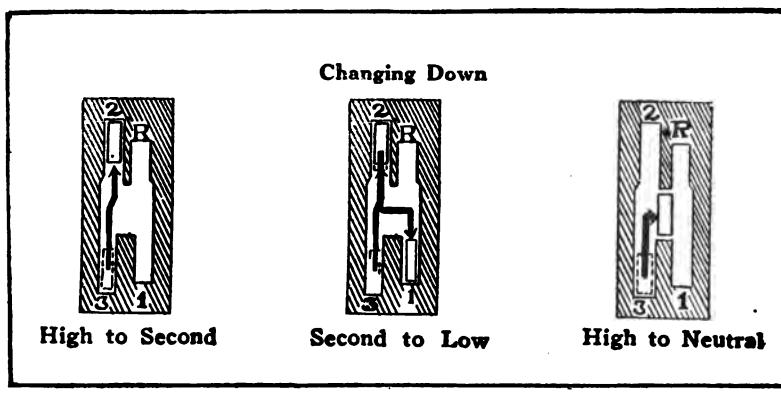


Fig. 266.—Method of Changing From Higher to Lower Speed Ratio.

Q. What should be done if another car desires to pass?

A. If a suitable warning signal is heard signifying the car behind wants to pass, one should go as far to the right as possible in order to provide the maximum space at the left for the overtaking vehicle.

Q. What appliance insures traction on slippery roads?

A. If tires of the plain round tread are used, traction on slippery roads will be materially improved by using some form of anti-skid chain which may be easily attached to the tire when needed and removed when they have served their purpose.

Q. When should the lowest gear ratio be used?

A. The lowest gear ratio should always be used when starting the car on a grade or when road surfaces are in very poor condition.

Q. When is the intermediate ratio desirable?

A. The intermediate gear ratios are always used when conditions of operation are too severe for the direct drive and yet the resistance is not so great that the low gear must be used. The intermediate ratio will often save the engine from laboring if used on sandy or muddy roads or when climbing gradients. Better speed can be made on the intermediate ratio over unfavorable road surfaces than can be attained with the direct drive.

Q. Why is the direct drive or high speed the best suited for average conditions?

A. When the lower gear ratios are used considerable power is absorbed by friction of the gears in the change speed gearset whereas on the high speed or direct drive position practically the only power lost is at the driving gears in the rear axle. The lower ratios are also apt to be noisy whereas the direct drive is more silent. When in the direct drive position there is practically no wear on the change speed gears and for this reason it is desirable to drive a car by throttle control with the high speed engaged as much as possible.

Q. When climbing a grade, how does the operator know when to shift from a higher to a lower ratio?

A. When climbing a grade with either the low or intermediate speed engaged an acceleration of the engine speed without a corresponding movement of the spark or throttle levers means that the resistance is lessened and that the car will probably take the grade on a higher ratio. The method of changing from a low speed to the direct drive with a three speed selective gearset is clearly shown at Fig. 265. The clutch pedal is depressed and the gear shift lever is moved from the low speed position to the second speed and the clutch again re-engaged to see if the engine will pull all right on this ratio. If the engine speed continues to accelerate the hand lever may be pulled back from position 2 to position 3 which engages the direct drive or highest ratio.

Q. How can the driver tell when to shift from a high to a lower ratio?

A. If the engine begins to labor when in the high gear and open-

ing the throttle more does not produce an acceleration of car speed it is an indication that the resistance is becoming too great for the amount of power available and that it is necessary to shift down to a lower ratio. This may be done as indicated at Fig. 266. First step is to go from the high speed position to the intermediate speed and if the engine continues to labor on the intermediate speed the lowest gear ratio should be engaged.

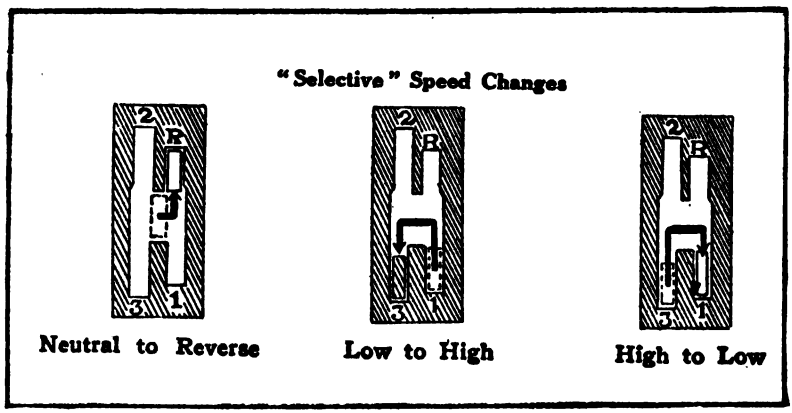


Fig. 267.—Showing Selective Speed Changes on Overland Car.

Q. Is it desirable to slip the clutch when slowing down car?

A. It is not good practice to slip the clutch to reduce car speed because the slipping produces rapid wear of the frictional material on clutches of the cone type and will produce wearing of the parts and heating in clutches of the plate and multiple disc patterns.

Q. Why should clutch be disengaged when brakes are applied?

A. If brakes are applied without releasing the clutch the braking members are called upon not only to arrest the car momentum, but also to absorb the engine power, which they are not designed to do.

Q. Why is it desirable to accelerate speed of car before reaching an upgrade?

A. If road conditions are favorable and a car is speeded up before it reaches an up grade it will acquire considerable momentum which will assist the engine in overcoming the grade resistance.

Q. What is the best process of descending steep hills?

A. When descending a steep or long hill it is well to release the clutch lever and throw off the switch in order to stop the engine. When the bottom of the hill is reached and before the car speed has been checked appreciably, one can throw the switch back in operative position and when the clutch is re-engaged the engine will start. The advantage of coasting is that not only is wear reduced appreciably and some fuel saved but the engine is given a chance to cool down and the car can be checked much more easily if allowed to descend a hill by its own momentum.

Q. How can the engine be used as a brake?

A. In event of failure of the regular braking members a decided retarding effect may be obtained by placing the gearshift lever in the low or intermediate speed position, throwing off the ignition switch and applying the clutch so that the rear wheels must turn the engine against compression. This virtually turns the engine into an air compressor and it will absorb considerable power.

Q. Describe general precautions regarding lights, warning signals and license hangers that will insure against trouble in most States.

A. The laws of most States call for the use of adequate brakes, a suitable warning signal, and lights at night as well as the display of license tags issued by that State or home State of the motorist. Visiting motorists going from one State to another are not required to take out a new license in every State they pass through, unless they intend to stay over ten days. The license hangers must be displayed in an easily seen location and must be kept clean and should be so placed that they will be illuminated after dark. The laws generally call for a red light in the rear which will throw a white light on the license number and two white lights on the front of the car which will be easily discernible two hundred feet from the car.

Note.—See Appendix for Digest of State Motoring Laws.

LESSON THIRTY

OILING THE MOTOR CAR CHASSIS

Q. What is the most important part to oil in the automobile?

A. The power plant is the most important part of the automobile chassis and in order to obtain continued efficient operation without overheating or diminution of power it is necessary to keep all interior working parts covered with a film of oil.

Q. What grade of lubricant is necessary for the engine, and how is it applied?

A. Only the best grade of cylinder oil should be used to lubricate the internal combustion motor and the viscosity or body required will depend upon the individual requirements of the power plant. Some engines have very closely fitting pistons and rings and tightly adjusted bearings which means that a light bodied oil must be used in order to form a film between the closely fitting parts. Other engines will operate better on medium grade oils, while an engine that has been run for a time so that the working parts have freed up will require heavier bodied oils in order to cushion the shock between worn parts.

In the simple forms of constant level splash feed lubrication systems the oil may be introduced through breather pipes in the side of the crank case, as indicated at Fig. 268. In some power plants a mechanical oiler having individual pump feed is utilized as shown at Fig. 269. In this case in addition to introducing oil through the breather pipes *G* and *K* the mechanical oiler must be kept filled. This lubricator is driven by an extension of the pump shaft and has independent adjustments so the amount of oil going to each cylinder through the individual leads may be varied at will. The screw *A* regulates the oil supply to the rear cylinder, *B* to the third cylinder, *C* to the second cylinder and *D* to the first cylinder.

The screws *E* and *F* regulate the amount of oil supplied the timing gear case. The breather pipe *G* is provided with an easily removable cap and is used as an oil reservoir filling tube, while the breather *K* which has a non-removable screen at the top is used only for relieving crank case compression.

In the motor shown at Fig. 270 a sight indicator which shows the level of oil in the crank case gives notice when it is necessary to insert more lubricant through the oil filler opening at its side. Most motors used to-day employ one of the breather pipes as a

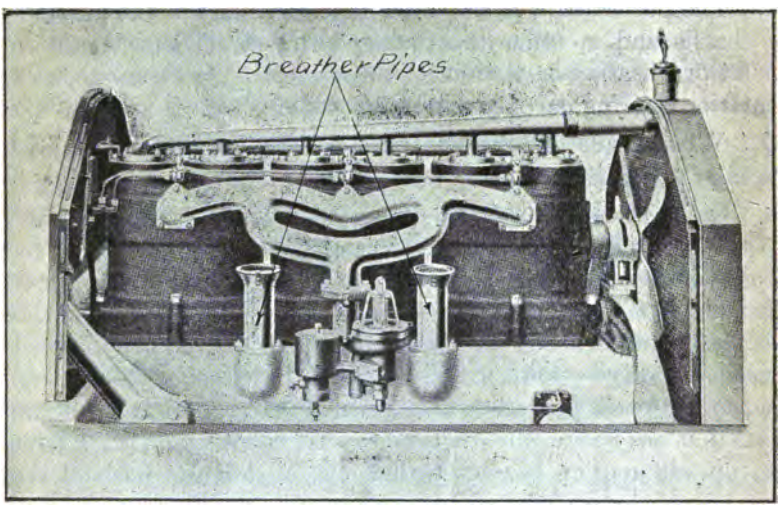


Fig. 268.—Showing Breather Pipes Through Which Oil May Be Introduced in Engine Base.

filler and as the oil is carried in a sump integral with the crank case it is not difficult for the lubricant to reach the container when introduced through the crank case compression release tubes.

Q. Does the oil from the interior lubricate all parts of the power plant?

A. The oil supplied to the interior of the motor is depended on only to lubricate the parts contained in the engine crank case; these include the piston and cylinder walls, the piston rings, upper and lower connecting rod bearings, the main crank shaft bearings, the

journals supporting the cam shaft, the cams, the valve operating plungers, and in some cases, the timing gears. There are a number of other points, however, on the exterior of the engine that need lubrication that cannot be reached from the interior.

Q. How are the exposed parts of engine lubricated?

A. In the engine shown at Fig. 269, for example, there are a number of exposed parts that need lubrication and that must be supplied either through the medium of a hand oil can or by grease cups

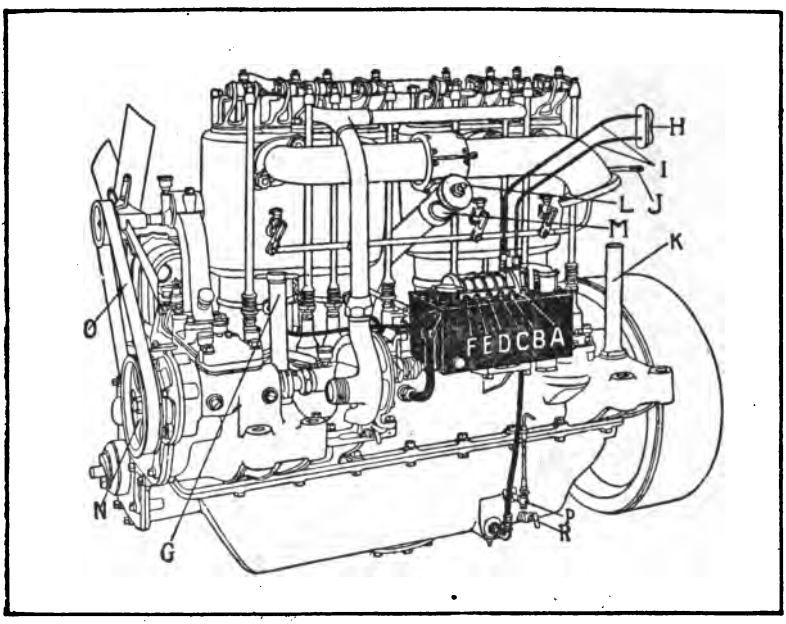


Fig. 269.—Pope-Hartford Engine With Individual Lead Mechanical Oiler.

attached to the points needing lubricant. On the top of the engine, each of the valve operating rocker arms is provided with a small oil cup at its fulcrum point, or bearing on which it rocks, so these pins may be oiled daily. Some grease cups are provided on the fan supporting bracket, the timing gear case and the pump bearings. These are also intended to be screwed down one or two turns every day.

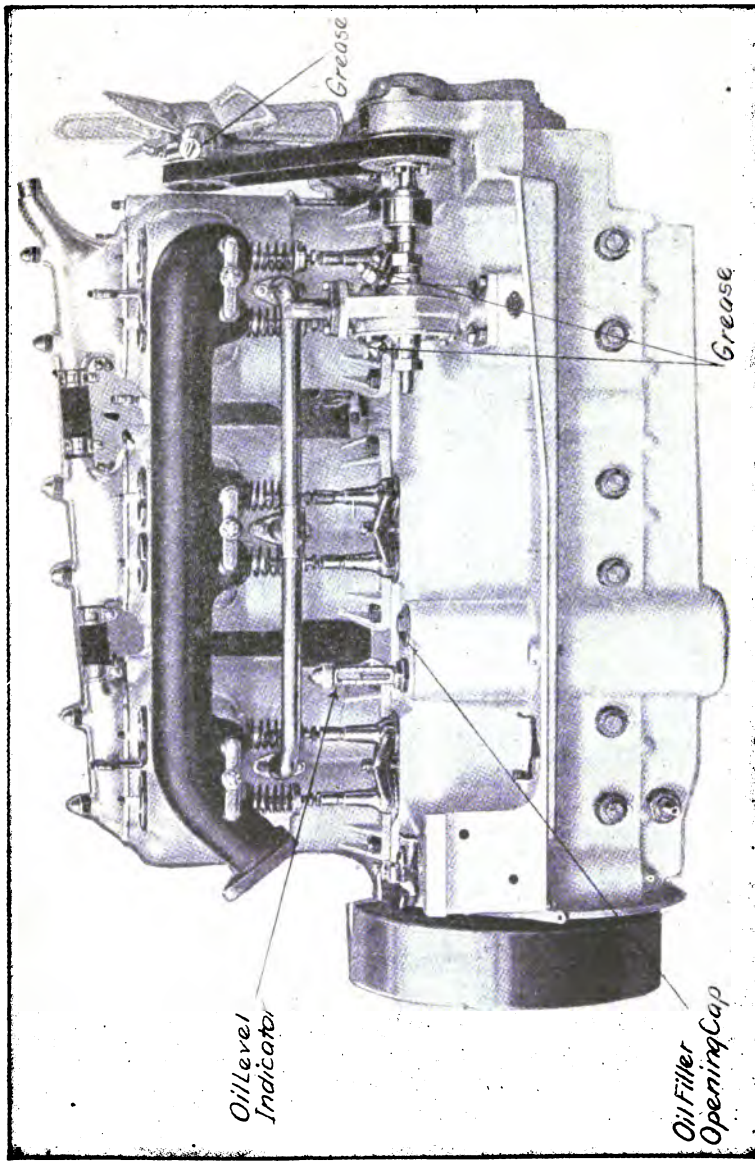


Fig. 270.—Lozier Six-Cylinder Engine Showing Grease Cups on Fan and Pump, Oil Level Indicator and Oil Filler Opening.

Q. What parts of cooling system need oil?

A. The only parts of the cooling system that require lubrication, other than that obtained from the interior of the engine itself, are the bearings of the fan hub and those of the pump.

Q. How are fan bearings lubricated, and how often should lubricant be applied?

A. As is clearly shown at Fig. 270, a small grease cup is screwed into the fan hub and a few turns of this member suffices to lubricate the fan properly for several hundred miles of car service.

Q. What is the method of lubricating pump bearings?

A. Bearings of the circulating pump, which are of the plain bronze bushing type, need certain quantities of lubricant and this is introduced through small grease cups attached to the pump casing which are given a couple of turns each two or three hundred miles of car service.

Q. What parts of ignition system need oil?

A. Practically the only points in the igniti n system requiring lubrication are the bearings of the magneto armature or the rotating parts of a primary timer.

Q. Describe lubricant to use in magneto and specify all points needing it.

A. The magneto armatures, for the most part, as well as the distributor shafts, are supported on anti-friction bearings of the ball type, and the mistake is often made of applying too much lubricant. Most magnetos have three oil holes, one over each armature bearing and one communicating to the distributor shaft bearings. Three or four drops of light sewing machine oil applied to each of these oil holes every five hundred miles of car operation is all that is necessary. A few drops should also be introduced on the rubbing parts of the contact breaker at the same time the rest of the device is oiled. If a magneto is oiled too freely, the armature may become oil-soaked which will injure the insulation and facilitate short circuit. In any event too much oil will cause serious trouble in the distributor or contact breaker by interfering with proper electrical contact of the platinum points or carbon

brushes utilized to close the primary and secondary circuits respectively.

Q. What kind of lubricant should be used in primary timer?

A. A primary timer of the rolling contact form should be lubricated with a few drops of the same light dynamo oil or sewing machine lubricant that is used in the magneto bearings. Never use lubricants containing graphite around electrical apparatus.

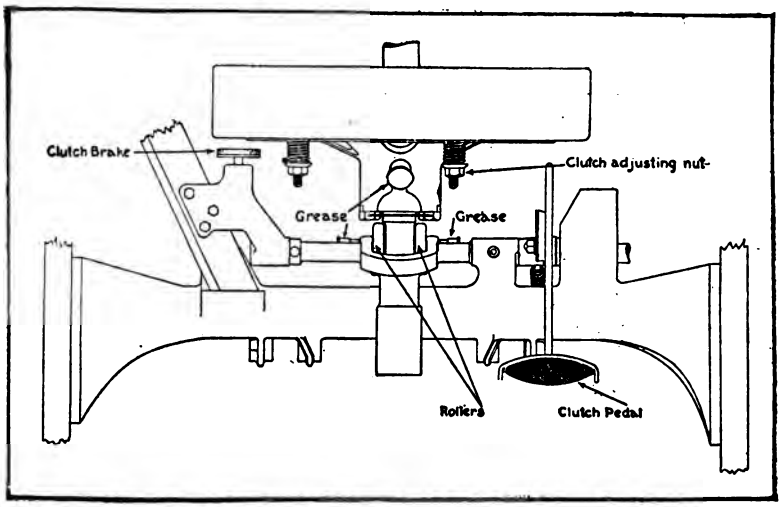


Fig. 271.—How Grease Cups Are Applied for Clutch Lubrication.

Q. What types of clutches need oil, and how is it applied?

A. Plate clutches of the multiple disc pattern are the only types designed to run in lubricant and for the most part these revolve in a bath of oil. The general rule is to drain out the clutch case every five hundred miles or so, flush out with kerosene in order to clear out all sediment and then refill with from one to two quarts of either a very light machine oil or a mixture of one-half cylinder oil and one half kerosene. The amount of oil supplied, obviously, depends upon the capacity of the clutch case.

Q. Are there any clutches that can be run without oil?

A. Practically all cone clutches whether faced with leather or Raybestos and multiple disc clutches of the dry plate type are de-

signed to run without lubrication. Applying oil to clutches of this character will reduce the friction adhesion to such a point that they will not transmit power.

Q. What parts of all clutches need lubrication?

A. The actuating yoke and the bearings on which the clutch driven member revolves when it is declutched require lubrication on all types of clutches. A typical clutch yoke assembly and the points needing lubrication are outlined at Fig. 271.

Q. What is the best lubricant for clutch actuating yoke or releasing rolls?

A. The clutch actuating yoke, when of the plain bearing type, is oiled with a small compression grease cup and the rolls carried by the releasing yoke in some types are also lubricated with grease because this substance is not apt to be squeezed out by the pressure existing at this bearing point. A grease cup also communicates with the thrust and radial bearings, used to support the clutch driven members.

Q. What points of friction disc transmission need oil?

A. The bearing points on the cross shaft and on the friction driving disc shaft are usually of the anti-friction type and are packed in grease and the supply is renewed through small compression grease cups. The path for the sliding driven disc should also be kept well lubricated with oil so that this will move freely from one point to another in obtaining speed changes.

Q. Describe method of oiling planetary gearsets?

A. Planetary gearsets are either housed in a casing so they revolve in an oil bath as in the Ford automobile or are carried in oil tight cases which may be filled with a light semi-fluid mineral oil through a suitable filler plug in the side of the gear case as in Buick cars.

Q. What is the common method of lubricating sliding gear transmission?

A. Sliding gear transmissions are invariably designed so the gears revolve in a mass of lubricant contained in the gear case.

Transmissions of this nature are provided with a large removable cover plate, as shown at Fig. 272, and the grease may be easily introduced into the gear case to replenish any waste lubricant. As a rule, the transmission case does not require attention more often than once in every two thousand miles and at the end of this period

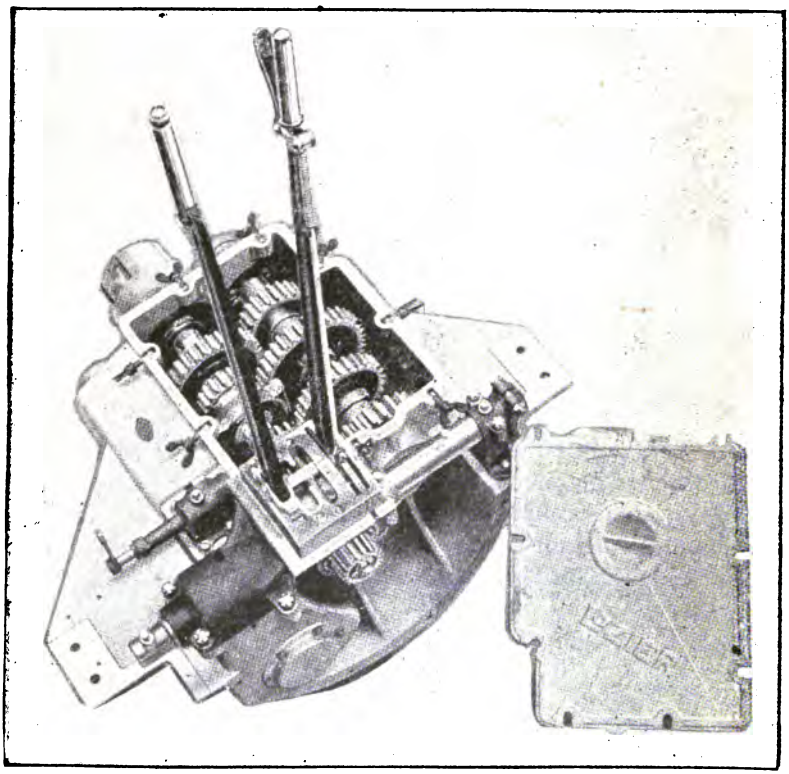


Fig. 272.—Typical Gearcase With Cover Removed to Show Large Opening Through Which Lubricant May Be Introduced.

of operation it is advised by many authorities that the gear case be thoroughly cleaned and flushed with kerosene to remove all traces of the old grease and any metallic particles that may have been dislodged from the gear teeth. Some gears are designed to run with a moderately viscous graphite grease while other forms are

designed to operate in a very heavy cylinder oil such as used in steam engines.

Q. Are lubricants containing cork or wood fibers desirable for use in gearsets?

A. Some makers advertise greases that are guaranteed to silence noisy gearsets. These contain particles of cork or shredded wood designed to fill the space between the worn gear teeth and cushion the shock that oil or grease would not be capable of doing by itself. These greases should never be employed in gear sets if efficient operation is desired because they not only interpose an item of serious frictional resistance and consume power but are also entirely unsuited for the anti-friction ball or roller bearings used to support practically all change speed gear shafts.

Q. Why are greases containing animal fats or other organic fillers undesirable for motor car use?

A. Greases adulterated with animal fats to give them more body are unsuited for lubricating the motor vehicle parts because they become rancid after they have been used for a time and they liberate fatty acids which will injure the finished surfaces of the gears and anti-friction bearings. Greases of this nature gum up very easily and as they harden the revolving gears will cut paths in which they turn and no lubricant is supplied to the gear teeth though the transmission case may be half full of the solidified grease.

Q. What points of chain driving systems require lubrication?

A. The chains are practically the only parts requiring lubrication as the bearings of the jack-shaft and rear wheels are taken care of by suitable grease cups or lubricant packing while the sprockets will always receive sufficient lubricant from the chains.

Q. Describe method of lubricating driving chains.

A. Chains should never be lubricated by the indiscriminate application of oil or grease to the exterior, as this coating serves merely to collect road dust and grit which acts as an abrasive material to produce rapid depreciation of the chains and sprockets.

The chains should be removed every five hundred miles and thoroughly cleaned with kerosene to remove all accumulated dirt and especially to wash the grit out from the joints in the chain links. After the chains have been thoroughly cleaned by being allowed to soak for a time in the bath of kerosene they are removed and immersed in a vessel of suitable size containing a mixture of mineral grease and graphite in a semi-fluid condition which has been produced by heating. After the lubricant has had ample opportunity to penetrate into all the crevices between the chain links, rollers and bearing rivets, the chain is removed and the surplus lubricant wiped from the outside. The sprockets have been thoroughly cleaned while the chains have been cleaned or lubricated and the chains can be replaced without lubricating the sprockets.

Q. How are universal joints lubricated?

A. Universal joints are generally encased in grease retaining housings and do not need lubrication oftener than every month, or every thousand miles of car service. The dirty grease is removed by flushing out with kerosene and the joint may be refilled with transmission oil or light mineral grease depending on the construction. Some universal joints are provided with small compression grease cups which may be screwed down from time to time, while others mounted at the front end of a torque tube axle employing but one universal joint are provided with a separate oil lead from a mechanical oiler or with a large grease cup which lubricates the ball joint in which the universal joint is carried as well as the parts of the joint.

Q. Describe rear axle points needing lubrication and outline the lubricants to use.

A. There are a number of points in the rear construction that require lubrication, these being clearly shown at Fig. 273. The differential assembly and the driving gears as well as the bearings supporting these members are designed to operate in a constant bath of lubricant carried in the differential gear case. The wheels revolve on bearings of the anti-friction type and these are also contained in grease retaining, dust excluding housings. The brake actuating rod bearings and the various minor joints, such as the rotat-

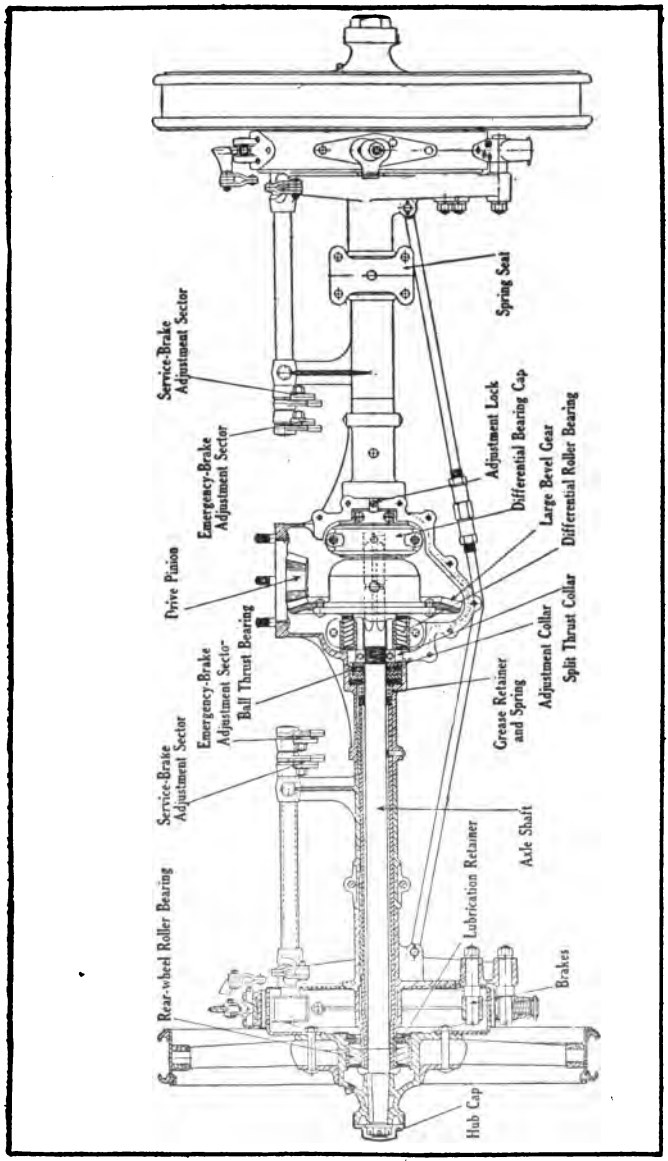


Fig. 273.—Outlining Principal Parts of Rear Axle, Differential Exposed Showing Opportunity to Introduce Grease Packing.

ing spring chairs or seats and the various yoke and lever connections can be oiled from a hand oiler from time to time.

Q. How often should differential and driving gear assembly be greased?

A. The rear axle differential casing should be drained thoroughly of all lubricant and flushed out with kerosene every thousand miles. Some differential assemblies use a mixture of transmission oil and cylinder oil, others use light graphite grease, and in any event, enough lubricant should be placed in the case so it will reach nearly to the under portion of the driving shaft. A heavier lubricant is needed in hot weather than during the winter months when a mixture of half cylinder oil and half transmission oil is recommended.

Q. How often are wheels lubricated?

A. The wheel bearings are taken down, cleaned and repacked with light mineral or graphite grease every thousand miles.

Q. What points on the front axle need greasing, and how often?

A. The principal points of the front axle that need frequent attention are the small oilers or grease cups provided on the steering knuckle bolts and on the steering connections. The wheel bearings, which are contained in a grease tight hub, are packed in lubricant, the supply of which is renewed after the hub interior has been thoroughly cleaned out every thousand miles. A typical front hub assembly mounted on taper roller bearings is clearly outlined at Fig. 274, which also shows the grease cups carried on the end of the steering spindle bolt which supplies lubricant to the roller bearings that take the weight of the car and make for easy steering.

Q. Where are steering gears lubricated?

A. Practically all steering gears have enclosed reduction gears and these are lubricated by a grease packing which need not be renewed except during the yearly overhauling. When the steering tube to which the wheel is attached passes through an outer casing, it is necessary to put a few drops of oil into this casing every week in order to prevent rusting and sticking of one tube inside of the

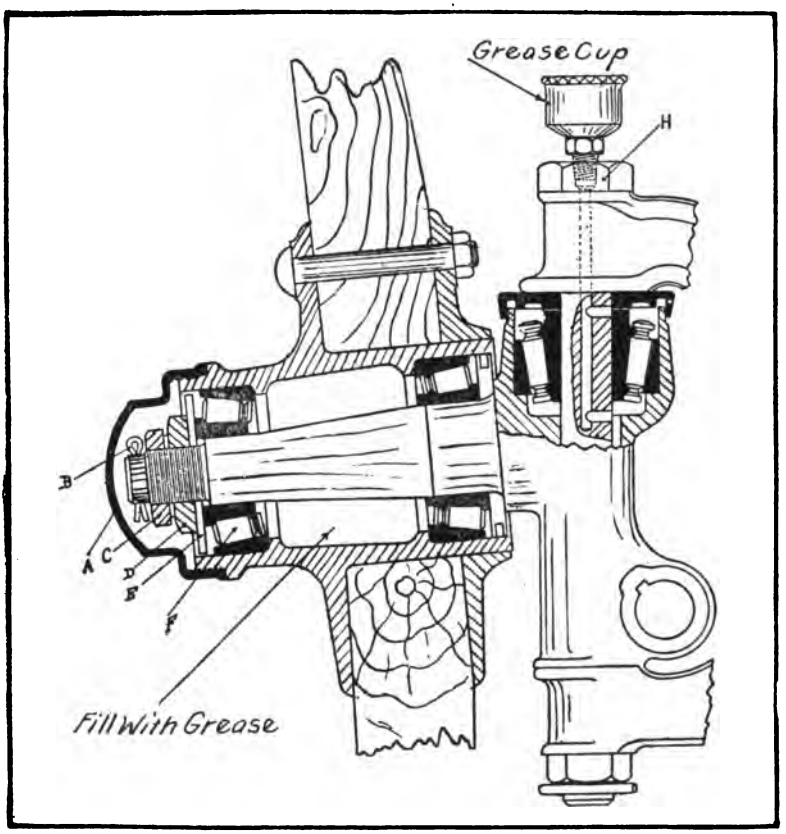


Fig. 274.—Showing Bearings in Hub of Front Wheel and Points on Steering Spindle Needing Oil.

other. The motor control rods also pass through the interior and while no provision is made for lubricating these as a rule it is good practice to loosen the connections at their lower end and lift them out of the steering tube far enough to permit of oil being introduced. This need not be done oftener than two or three times a season.

Q. What frame parts need oil, and how often?

A. There are a multitude of small points of minor importance on the chassis that require lubrication in order to prevent untimely

depreciation. Among these may be mentioned the clutch and brake pedal supporting shaft, the control lever shafts and the bearings for these members; the ends of the radius rod or torque tube, the various minor joints or yoke connections at the end of the spark and throttle lever members and the brake rods and other moving points where no regular provision is made for lubrication. These points should be gone over every two hundred and fifty or three hundred miles with a hand oil can containing heavy oil.

Q. Why should control lever tubes and bearings be oiled?

A. While the gear shift and emergency brake levers have only an oscillating movement and in the case of the selective transmission the gear shift lever may have a sidewise motion, it is necessary to oil these regularly because the control tubes may become rusted. As the shaft and tube for the emergency brake and gearshift lever are usually mounted one inside of the other, any deposit of rust will cause binding and will interfere with gear shifting or brake application. The same reason applies for lubricating the clutch and brake operating pedal.

Q. Describe lubrication of springs and outline best method of introducing oil between the spring leaves.

A. The spring shackles of practically all cars, even those of the cheaper runabouts, are provided with oil holes or small grease cups through which lubricant may be introduced at the bearing points between the spring eye and the shackle bolt. About once or twice a season it is good practice to introduce oil between the spring leaves in order that these members shall slide over each other freely which reduces the tendency to squeak, as well as improving spring flexibility. There are two methods of separating the spring leaves without actually taking the spring apart. One of these is to jack up the car by placing the weight raising jacks under the frame members so that the car weight will be taken off of the axle and springs. After the frame has been raised to the required height so the wheels clear the ground the weight of the axle construction will tend to separate the leaves of the springs slightly and graphite grease may be introduced between them with a thin piece of sheet

brass or steel or the oil may be squirted in from the hand oil can. The best method of introducing oil is by using a simple fixture, as outlined at Fig. 275-A. This has two points, one of which is fixed, while the other is slidably mounted on a rod forming the backbone of the device. A threaded screw provided with a T handle is adapted to bring the points together and as considerable pressure may be exerted on the thread of the screw it is possible to spread the spring leaves and introduce oil as shown at *B* without jacking up the car.

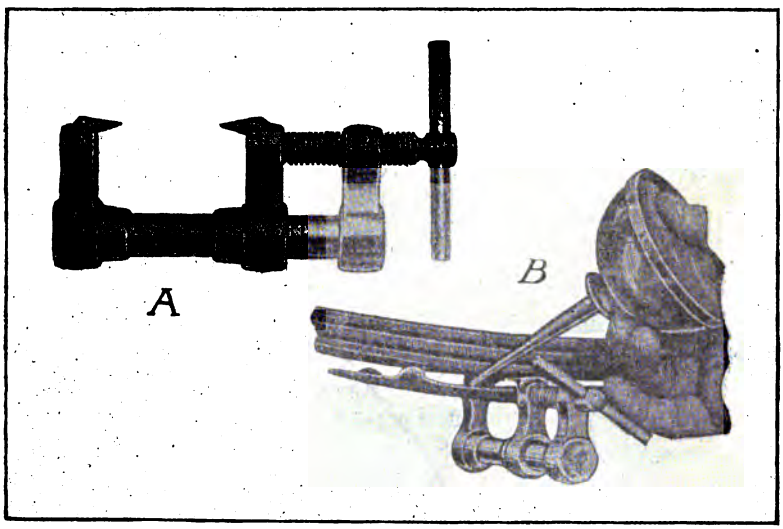


Fig. 275.—Outlining Simple Method of Putting Oil Between Spring Leaves.

Q. What parts of a car should be kept free from oil or grease at all times?

A. Among the parts of the car that should be kept free from excessive accumulations of oil or grease may be mentioned the spark plugs and magneto of the ignition system, all electrical wiring, the clutch when of the cone or dry plate type, the brakes and the tires. Oil will rot rubber rapidly and any grease thrown on the tires from

the axle should be wiped off immediately when discovered in order to prevent deterioration o the casing The same applies to the rubber insulation of the electric wiring.

Q. How can one tell if there is too much oil in the engine, and what is its effect?

A. Overlubrication of the motor is apt to produce carbon deposits and overheating because of these accumulations in the combustion chamber and also results in loss of power on account of the carbon deposits which may gum up the piston rings or the valves. If too much lubricating oil is supplied the engine the exhaust gas will be bluish white in color, and the amount of surplus oil is readily indicated by the density of the smoke. A light smoke when the engine is speeded up is not necessarily a sign of overlubrication and some closely fitted engines, especially those of the sleeve valve type, require to be copiously lubricated at all times.

Q. What are the indications of not enough oil in the power plant?

A. If the engine seems to lose power and overheat and the trouble is not due to defective carburetion or cooling one should suspect that the engine is not receiving lubricant enough. The indications of lack of lubricant are so pronounced that they are readily recognized by even the novice and it is only in cases of extreme carelessness that the engine may get dry enough to indicate its distress by squeaking or grinding noises.

Q. What is the result if an excessive amount of grease is supplied to the gearcase or the rear axle?

A. Too much grease in the transmission or differential case is apt to be evidenced by leaking at the bearing points. This is especially noticeable in rear axles on account of the difficulty of having these members absolutely oil tight and still be free running. If too much grease is supplied to the differential case it is apt to run along the drive axles or shafts and escapes from the end of the axle into the brake drums from which point it is thrown around on the tire. This grease accumulation also interferes with the action of internal brakes.

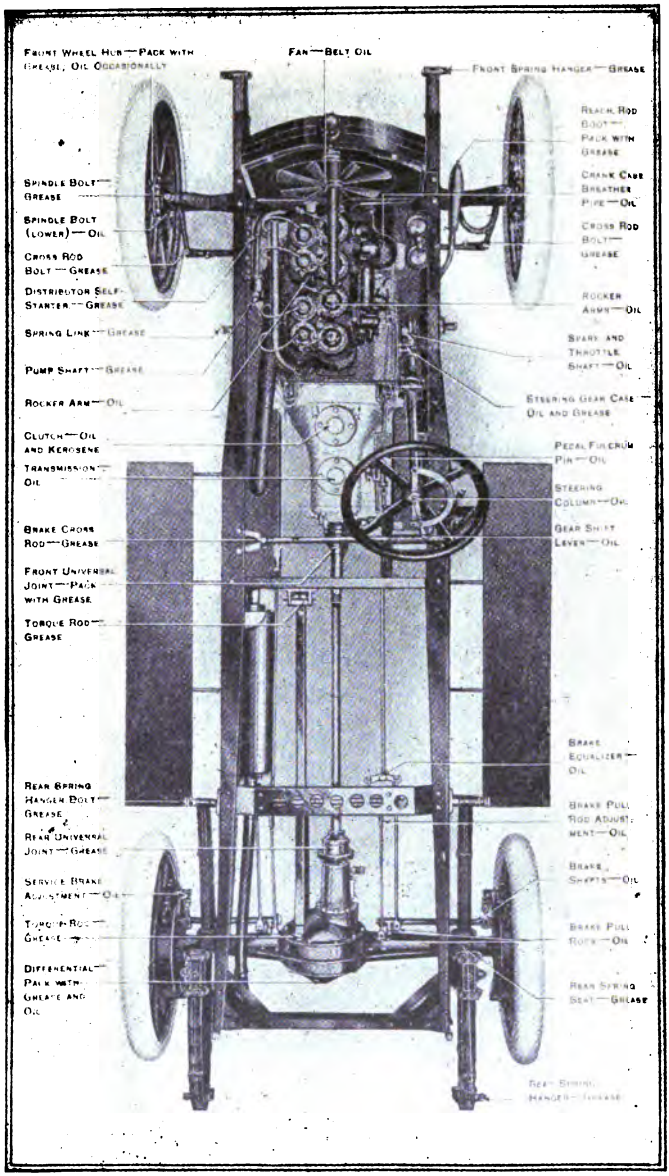


Fig. 276.—Chassis of Chalmers Car Showing Important Points Needing Oil.

Q. What is the basic rule to observe to secure efficient lubrication?

A. First of all, the motorist must be prepared to buy and use only the best oils and greases, especially for motor lubrication. This assurance is obtained by buying the product of only reputable manufacturers of lubricants and paying enough for them to procure material of the proper quality. The instructions given by most makers of cars for lubrication should be followed to the letter and the greases recommended by them should be used in preference to those the motorist might select for himself. A comprehensive lubrication chart showing the important points demanding lubrication on a Chalmers chassis is clearly outlined at Fig. 276 while the lubrication chart prepared by the engineers of the Overland Company is presented in the form of a folding plate, Fig. 276a.

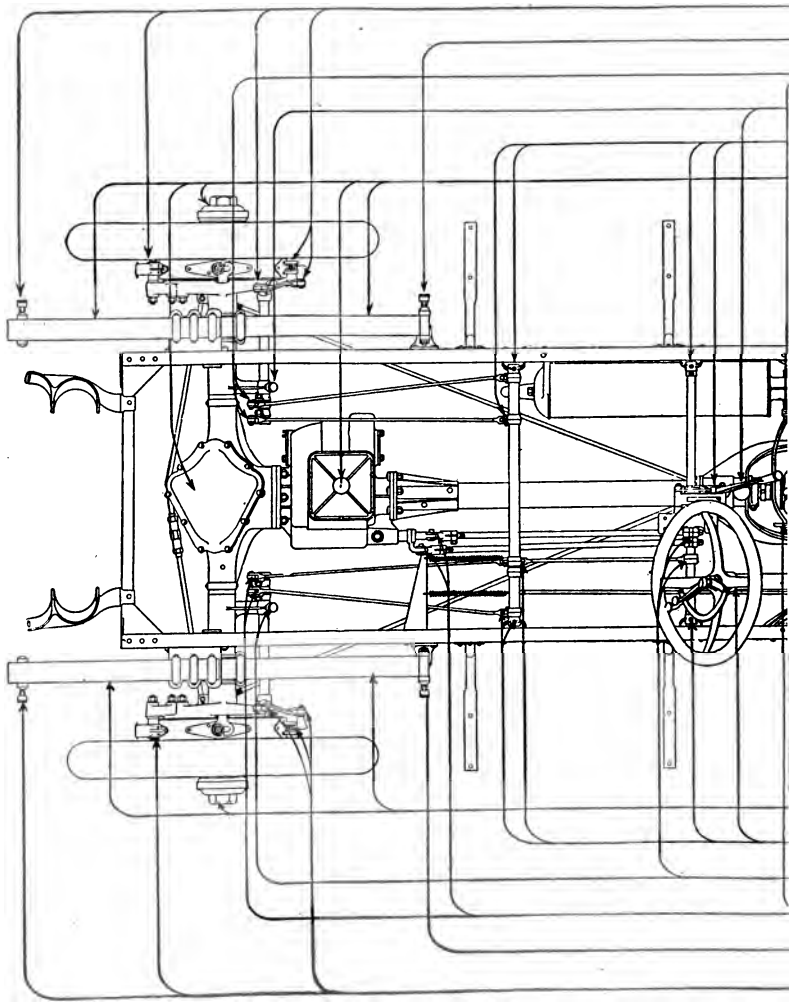
The schedule of lubrication appended applies to the Chalmers chassis but as this is typical of standard design the instructions given can be followed to advantage in other cars of similar construction.

EVERY DAY CAR IS IN USE, OR EVERY 100 MILES.

PART	QUANTITY	LUBRICANT
Crank case	Keep oil at level of top try cock.	Motor oil.
Steering knuckle	One complete turn.	Cup grease.
Steering knuckle grease cups.	One complete turn.	Cup grease
Steering cross rod grease cups.	One complete turn.	Cup grease.
All spring bolt grease cups.	Two complete turns.	Cup grease.
Eccentric bushing.	10 or 15 drops.	Motor oil.
Wheel hub oilers.	10 drops.	Motor oil.

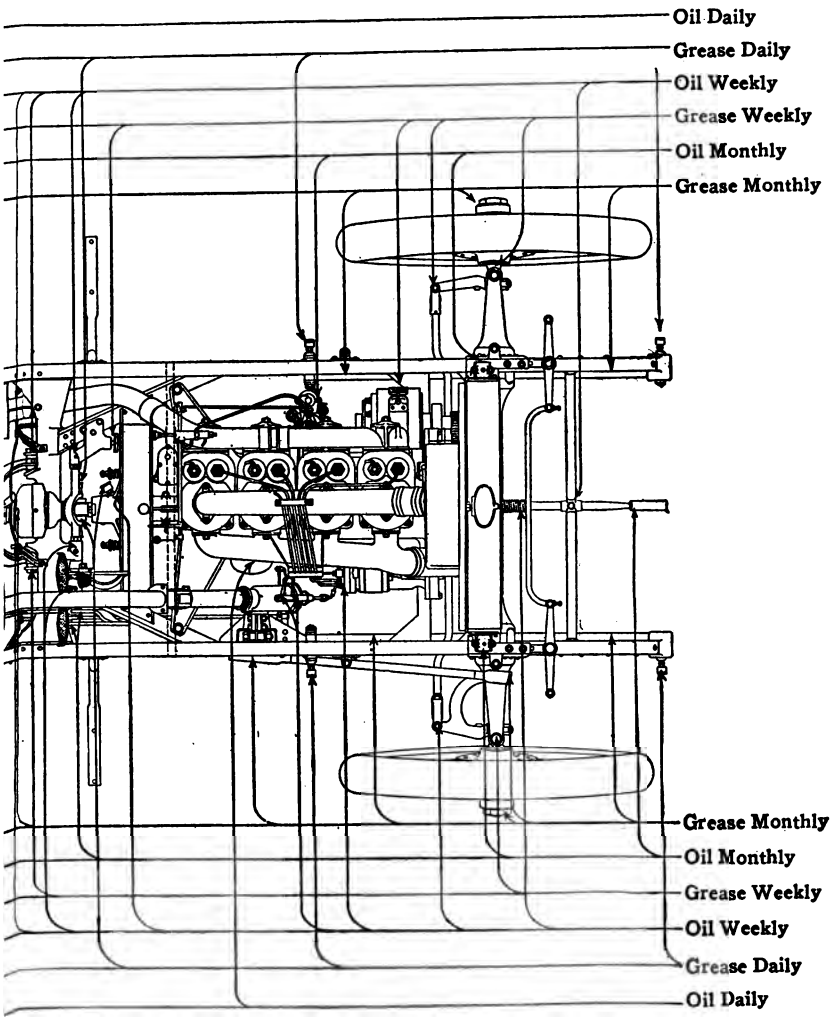
TWICE A WEEK, OR ABOUT EVERY 200 MILES.

PART	QUANTITY	LUBRICANT
Fan hub bearing.	Few drops.	Motor oil.
Pump shaft grease cup.	Two complete turns.	Cup grease.
Rocker arms.	Thoroughly.	Motor oil.



Lubricating Chart fo

Fig. 276A.—Lubrication Chart For Overland Mod



Overland Model 71

el 71 Can Be Used As a Guide for Similar Designs.

PART	QUANTITY	LUBRICANT
Steering gear case oiler.	Fill.	Motor oil.
Steering gear case grease cup.	Two complete turns.	Cup grease.
Steering wheel oil hole.	8 or 10 drops.	Motor oil.
Steering column.	10 or 15 drops.	Motor oil.
Self-starter distributor grease cup.	One complete turn.	Cup grease.

EVERY WEEK. OR ABOUT EVERY 300 MILES.

PART	QUANTITY	LUBRICANT
Starting crank bearing.	10 drops.	Motor oil.
Inlet valve covers.	Tablespoon.	Motor oil.
Spark and throttle shafts.	Few drops.	Motor oil.
Control bracket bearings.	Thoroughly.	Motor oil.
Transmission case.	Enough to cover lower shaft.	600 "W" steam cylinder oil.
Clutch casing.	Should contain 1 quart to 3 pints.	One-half motor oil one-half kerosene.
Pedal fulcrum pin.	Thoroughly.	Motor oil.
Brake pull rods and connections.	Thoroughly.	Motor oil.
Self-starter pump.	2 ounces.	600 "W" steam cylinder oil.
Brake cross rod grease cups. (Inside frame.)	Two complete turns.	Cup grease.
Torque rod grease cups front and rear.	Two complete turns.	Cup grease.
Brake shafts on rear wheels.	Thoroughly.	Motor oil.
Rear spring perch grease cups.	Two complete turns.	Cup grease.

TWICE A MONTH, OR EVERY 500 MILES.

PART	QUANTITY	LUBRICANT
Magneto bearings (3 oil holes).	3 or 4 drops each.	High grade light machine oil.
Clutch case.	Drain, flush with kerosene, refill with 1 quart to 3 pints.	One-half motor oil one-half kerosene.

EVERY MONTH, OR EVERY 1,000 MILES.

PART	QUANTITY	LUBRICANT
Crank case.	Drain off dirty oil, clean oil screen, fill to level of top try cock.	Motor oil.
Gear shifting rod case.	Pack thoroughly.	Cup grease.
Reach rod boots.	Pack thoroughly.	Cup grease.
Spring leaves (jack up frame and pry leaves apart).	Thoroughly.	Graphite grease.
Hub caps.	Pack thoroughly.	Cup grease.
Universal joints.	Remove grease hole plug and fill.	Cup grease.
Gasoline pressure hand pump.	4 or 5 drops.	Light machine oil.

EVERY 2,000 MILES.

PART	QUANTITY	LUBRICANT
Differential housing.	3 pints.	A mixture of two-thirds grease and one-third motor oil.
Transmission case.	Drain thoroughly, flush with kerosene, refill to cover lower shaft.	600 "W" steam cylinder oil.

DYNAMO SHOULD BE LUBRICATED EVERY 5,000 MILES.

When Changing Tires

Put a few drops of oil inside sliding ring of demountable rims to insure easy detaching.

Another very comprehensive lubrication schedule has been prepared by the Packard engineers for users of their product and as this gives very definite instructions regarding the lubrication of various chassis parts it is also presented for the reader's information as much of the advice can be applied with equal advantage to other motor cars.

EVERY DAY CAR IS IN USE, OR EVERY 150 MILES.

With cylinder oil.

Steering knuckle bolt oilers..... Fill.

With graphite grease.

Motor clutch shifter bearing sleeve grease cup	Two complete turns.
Motor clutch shifter shaft grease cup	One complete turn.
Steering connecting rod and cross tube grease cups	One complete turn.
Spring bolt grease cups	One complete turn.

EVERY WEEK, OR EVERY 300 MILES.

With cylinder oil.

Motor starting crank bearing	Eight or ten drops.
Shock absorber bearing studs	Thoroughly.
Rear axle truss rod forward connection	Thoroughly.
Rear axle brace oilers	Thoroughly.

With graphite grease.

Motor fan bearing grease cup	Two complete turns.
Rear axle outside bearing grease cups	One complete turn.

TWICE A MONTH, OR EVERY 500 MILES.

With cylinder oil.

Motor generator oil holes	Ten drops.
Spark and throttle adjusting clevis joints	Thoroughly.
Motor accelerator pedal joints	Thoroughly.
All brake adjusting clevises	Thoroughly.
External and internal brake fittings and connections	Thoroughly.
Hand brake cam oiler	Thoroughly.
Hand brake lever ratchet	Thoroughly.
Foot brake pedal bearing	Thoroughly.

With graphite grease.

Motor clutch pedal shaft grease cup	One complete turn.
Steering gear case grease cups	Two complete turns.

With cylinder oil and kerosene.

Change speed lever shaft bearings	Thoroughly.
Intermediate brake lever shaft and connections	Thoroughly.

With vaseline.

Motor generator grease tube.

EVERY MONTH, OR EVERY 1,000 MILES.

With cylinder oil.

Change speed reversing bell crank oiler	Fill.
Crank case	Drain off dirty oil, flush with kerosene and fill to pet cock level.

Magneto bearing oil wells.....Few drops.
Motor front gear compartment.....Drain thoroughly.

With graphite grease.

Front wheel bearings.....Clean with kerosene and repack.
Motor generator and magneto shaft universal joints.....Oil thoroughly.
Rear universal joint.....Remove grease hole plug and fill with grease again.
Front wheel hub caps.....Pack.
Motor water pump shaft universal joints....Thoroughly.

With gasoline.

Motor carburetor air valve stem.....Clean thoroughly. Do not oil.

With transmission oil.

Front universal joint.....Drain thoroughly, flush with kerosene and fill to pet cock level.
(Half cylinder oil and half transmission oil in cold weather.)
Rear axle case.....Drain thoroughly, flush with kerosene and fill to level of two brass plugs in under side of housing.
(Half cylinder oil and half transmission oil in cold weather.)
Rear axle transmission case.....Drain thoroughly, flush with kerosene and fill to level of button head screw in front cover.
(Half cylinder oil and half transmission oil in cold weather.)

ONCE A SEASON.

With graphite grease

Spring leaves.....Jack up frame to separate leaves, clean and lubricate thoroughly. Repeat whenever springs squeak.

LESSON THIRTY-ONE

ROAD TROUBLES AND THEIR SYMPTOMS

Q. In case of a sudden vehicle stop what should be suspected?

A. The general cause of a sudden motor car stop is either failure of the gasoline supply or of the ignition system. If the stop comes without warning, i. e., if the motor suddenly dies down, the first point to look at will be to see if there is any fuel in the gasoline tank and to look over the ignition system for broken wires. With battery ignition systems the breaking of a wire anywhere in the primary circuit will put the ignition system out of commission. With a transformer coil magneto system the failure of a single primary wire will also produce the same effect. In a true high tension magneto, about the only thing that will cause the motor to stop suddenly will be a premature short circuit of the regular ground wire leading from the magneto to the shut-off switch.

If there seems to be enough gasoline in the tank the trouble is due to either a broken or blocked up feed pipe or the gasoline shut-off pet cock at the tank may have jarred closed. A particle of dirt in the spray nozzle or the filter at the tank being filled entirely with dirt or water will also prevent gasoline reaching the cylinder. Sometimes the screen interposed in the pipe line to keep dirt out of the carburetor becomes clogged with lint or other matter of this nature and prevents the gasoline from flowing.

Q. How can one tell if ignition system is at fault?

A. The simplest method to ascertain if the trouble is due to the ignition system is to take the spark plugs out of the cylinders and keeping them connected up with their respective wires to see if a spark will pass between the points when the plugs are laid on the cylinder head and the motor cranked over. If sparks jump the gap between the points of the plugs the trouble is not due to ignition.

Q. What steps are necessary to find out if fuel supply system is responsible for the stop?

A. The amount of gasoline in the tank may be easily ascertained by inspection and if there seems to be enough the next thing to do is to uncouple the gasoline pipe at the carburetor after shutting off the valve at the bottom of the tank and then to note if a stream of fuel the full size of the orifice issues from the pipe when the gasoline shut-off valve is again open. If the gasoline does not flow it indicates that the pipe is stopped up. If the gasoline seems to be reaching the carburetor in proper quantities, the next point is to see if the spray nozzle is clogged up. A little gasoline is injected into the cylinders through the spark plug holes or the compression relief pet cocks and the motor is cranked over with a switch in place. If the motor starts and runs for a few revolutions it may be taken as an indication that even though the gasoline reaches the carburetor it does not reach the cylinders and the only defect that will prevent the gasoline from going into the mixing chamber is either dirt in the spray nozzle or in the passage between the spray nozzle and the float chamber. With carburetors of the adjustable spray nozzle type, dirt may often be cleared from the spray nozzle by screwing the gasoline regulating needle valve to its seat and then returning it to its running position. If that fails to clear the stand pipe the carburetor must be taken apart and thoroughly cleaned.

Q. Do oil or water systems fail without warning?

A. The lubricating or cooling systems are not apt to fail suddenly and motor stoppages due to either defective cooling or lubrication are rare because a failure in either of these groups will make itself evident some time before a motor actually stops because it has overheated or the parts seized through lack of lubrication.

Q. What should be looked for if an engine has no power but is running steadily?

A. If an engine is slowing down gradually and yet continues to explode regularly, this indicates either faulty lubrication or cooling.

Q. What should be looked for if engine loses power because of misfiring?

A. If an engine loses power on account of irregular operation or lack of regular sequence of explosions a number of defective conditions in carburetion, ignition or in the mechanism of the motor itself may be responsible for the faulty operation. These troubles are considered at length in the next lesson.

Q. What would cause a sudden knocking noise?

A. A sudden knocking or pounding noise from the interior of the motor usually indicates a loose or broken part.

Q. What would cause a gradually increasing knock?

A. If a motor is overheating because of faulty cooling or insufficient lubrication this condition will be evidenced by a knock or pound which will increase as the motor gets hotter. A gradually increasing knock is also sometimes caused by driving up an incline with the spark lever too far advanced.

Q. What parts of power plant produce knocking?

A. Worn or loose bearings on the crank shafts or connecting rods are the usual causes of knocking. Carbon deposits in the combustion chamber also cause preignition, which is evidenced by pounding.

Q. What does a loud squeak indicate?

A. A loud squeak is usually produced by a dry bearing and the car should be stopped as soon as a noise of this nature is heard and a search made to locate the cause.

Q. What does a loud hissing noise indicate?

A. A hissing noise shows a leak in the combustion chamber and is sometimes caused by a cracked or broken spark plug porcelain, a loose insulator in a spark plug, or a compression relief pet cock has either jarred open or the small spigot member or plug has dropped out of its center allowing the gases under pressure to escape.

Q. What does a noisy exhaust show?

A. A noisy exhaust shows a leak around the exhaust manifold or a disconnected muffler pipe if the cut-out valve is not open.

Q. What does steam coming out of the radiator indicate?

A. If a radiator is steaming it indicates that the motor is over-

heating. This may be due to lack of water in the cooling system or to defective lubrication.

Q. Is steam always a sign of serious trouble?

A. Steam from the radiator does not necessarily indicate serious trouble because if the motor has been run continuously for some time on one of the lower gear ratios as in hill climbing it may heat up enough to cause the water to boil and no serious injury will result if the supply of water in the radiator is augmented with cooler water. Driving on a retarded spark will also cause the radiator to steam as will a broken fan belt or excessively rich mixture.

Q. What does a rattling noise indicate?

A. A rattling sound is generally produced by some loose part of the chassis, which has become partially free of its restraining bolts or fastenings but which is still in place because it is held by some other member. Rattling noises are generally caused by loose mud guards, brakes or various operating rods extending from the operating levers or pedals to the parts they actuate.

Q. Suppose the car stops and the rear wheels do not turn, but the motor continues to run and the gear shift lever is in its proper position, what should be looked for?

A. The first thing to see is that the clutch is not slipping as very often the interlock between one of the brake levers and the clutch shifter will hold the clutch out of engagement if the brake lever is only partially applied or if adjustments have just been made. The clutch may be engaged properly but yet the connection between the clutch and the gearset may be broken. The gear lever may be in operative position but a pin may have sheared off so that the gears in the transmission case always remain in neutral position and do not shift or change positions when the speed lever is moved.

Q. Suppose the motor operates correctly and the gears in the gearset are turning, but the car does not move, where is the trouble apt to be?

A. Under the conditions stated the defect would exist in the driving mechanism at some point. A pin or driving key may have

sheared off in the universal joint or bevel drive pinion or the propeller shaft may have become broken. The adjustment of the bearings holding the differential case may have loosened up so the ring gear has moved over out of engagement with the driving pinion. The rivets or bolts holding the ring gear to the differential case may have sheared off so that the gear is turning without producing movement of the differential casing. One of the driving shafts may have broken in the axle housing between the differential and the wheel hub or a hub cap on a full floating hub may have come off and allowed the driving shaft clutch to come out of engagement with the corresponding member on the hub. The troubles enumerated are uncommon, however, though they have occurred often enough to warrant suspicion if the condition outlined should materialize.

Q. Suppose the car does not run freely down hill with the power shut off and the clutch released, what is the trouble?

A. This may be taken as an indication of binding or undue friction in the wheels or driving system. The most common cause is binding brakes because they are adjusted too tightly.

Q. What is the trouble when a car jumps or runs in irregular spurts?

A. This trouble is often caused by the motor running unsteadily or misfiring and then running on all cylinders for a time relaxing again into the condition of irregular operation where only part of the cylinders are working. If the engine is running steadily this jumping may be due to a partially slipping clutch which transmits the power correctly at times and does not take hold properly at other times.

Q. What should be looked for if gears do not shift well?

A. If trouble is experienced in shifting gears one should examine the clutch to see if this member releases promptly and does not spin. Sometimes the gear teeth may have become burred and will not engage properly or the defect may be due to wear or binding in the connection between the gear shift lever and the sliding gear actuating fork.

Q. What is the reason when a car does not stop promptly?

A. If a car does not stop within a reasonable time after the

clutch lever is released and the brake applied it signifies that the brakes are not holding as well as they should and that they either need readjustment or renewal of the frictional material.

Q. What is at fault if a car starts forward suddenly as soon as clutch is engaged?

A. If the car jumps forward with the clutch pedal let in gradually it means that the clutch is engaging too harshly and that there is lack of resiliency in the clutch facing if a cone type is used or lack of oil in a multiple disc form

Q. What does erratic steering indicate?

A. If trouble is experienced in steering the car and the steering wheel works freely there are two points that demand immediate inspection. The first thing to do is to make sure that the tie-bar joining the steering spindle arms is not loose or detached at one end and that the drag link and steering arms are also properly joined together. The second point to be examined and the most common trouble is a deflated front tire. Erratic steering is sometimes caused by a defect of the differential gear which prevents it from functioning properly.

Q. What does a loud explosion indicate?

A. A blowout in either front or rear tires is generally evidenced by a loud pop which may sound in some cases like a gun shot. It is due to the sudden escape of air confined under high pressure to the outer air and the noise is produced by the same cause as when an inflated paper bag is suddenly broken.

Q. What does "bumping" indicate?

A. "Bumping" is a sure indication of a flat tire on the rear wheels or a broken spring.

Q. What happens if one continues to run a car on a flat tire?

A. The outer casing and inner tube will be destroyed and the rim may be badly dented. In forms of tires of the straight wall type and in some quick detachable forms as soon as a tire becomes deflated it is liable to come right off of the wheel, as the air pressure is an important factor in holding it in place against the restraining rim member.

Q. What do sudden grinding noises in transmission case or rear axle indicate?

A. Grinding noises are generally caused by gearing out of adjustment or by particles of foreign matter such as metallic particles from broken bearings or stripped gear teeth working in between the gears from time to time.

NOTE.—For complete analysis of troubles see "The Modern Gasoline Automobile."—By Pagé.

LESSON THIRTY-TWO

REPAIRING POWER PLANT GROUP

Q. What are the main causes of lost power?

A. The principal causes of lost power are irregular engine operation, loss of compression if engine fires regularly, overheating and carbon deposits.

Q. Describe method of testing compression.

A. The easiest method of testing the compression is to turn the crank shaft over by means of the starting crank with all compression release cocks closed and spark plugs in place. The amount of resistance to cranking can be taken as an indication of the compression in the cylinders. A cylinder with good compression will offer decided resistance against rotation of the crank shaft, whereas one lacking in compression will offer no perceptibly greater resistance to the crank shaft than does bearing friction. If on turning the starting handle of a multiple cylinder engine one finds some cylinders that have good compression while others permit the gas to escape it is imperative that those having less compression should be found as these are the ones that need attention.

The amount of compression in a cylinder can be easily determined by various forms of pressure gauges that can be screwed into the cylinder head in place of a spark plug or compression relief cock. A gauge of this character is similar in construction to those used for showing the pressure of steam and the amount of compression is usually indicated on the dial. The various cylinders may be tested in turn and the compression should average at least 65 or 70 pounds per square inch in each cylinder. If no pressure gauge is at hand one may test each cylinder separately by removing the spark plugs or opening the relief cocks on all cylinders except that in which the compression is to be tested. Starting with the first cylinder each

of the other units is tested in turn and it is imperative that the compression be equal or nearly the same in all cylinders. The use of a pressure gauge is recommended because this gives a positive determination of the condition of the various members depended on to hold the gas under compression in the cylinder.

Q. What is the first thing to examine if compression is weak?

A. The first point to look at is the various gaskets and packings on top of the combustion chamber, such as those around the spark plug or under the valve chamber caps. It is easy to determine if

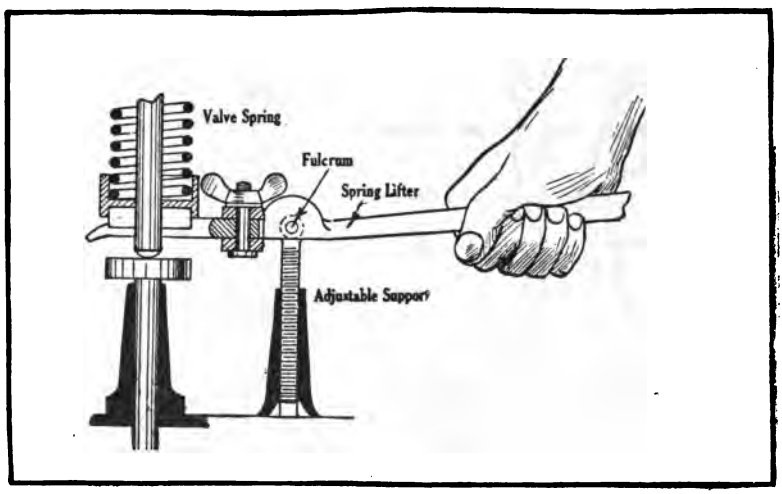


Fig. 277.—Methods of Relieving Valve Spring Tension to Remove Valve Stem Key.

these leak by squirting oil around the joints before cranking the engine. Any compression leak will be indicated by air bubbles. The next thing to examine are the inlet and exhaust valves. Valves that seat poorly are the main cause of poor compression and this defective condition is easily remedied, as a rule, by grinding the valves to a correct seating.

Q. Describe process of valve removal.

A. In order to remove the valves from the conventional form of cylinder it is first necessary to unscrew the valve chamber cap at

the top of the cylinder casting and also to remove the valve spring enclosing plates if these members are carried in a housing. The valves are kept seated by coil springs which expand against a key of some kind put through the valve stem and held in place by some form of collar that takes the valve spring thrust. In order to remove the valve it is first necessary to compress the spring sufficiently to draw the valve key out of the valve stem. This permits the valve to be lifted out through the top of the valve chamber.

A number of simple and easily operated devices are offered to facilitate valve removal. Some of these are shown at Figs. 277

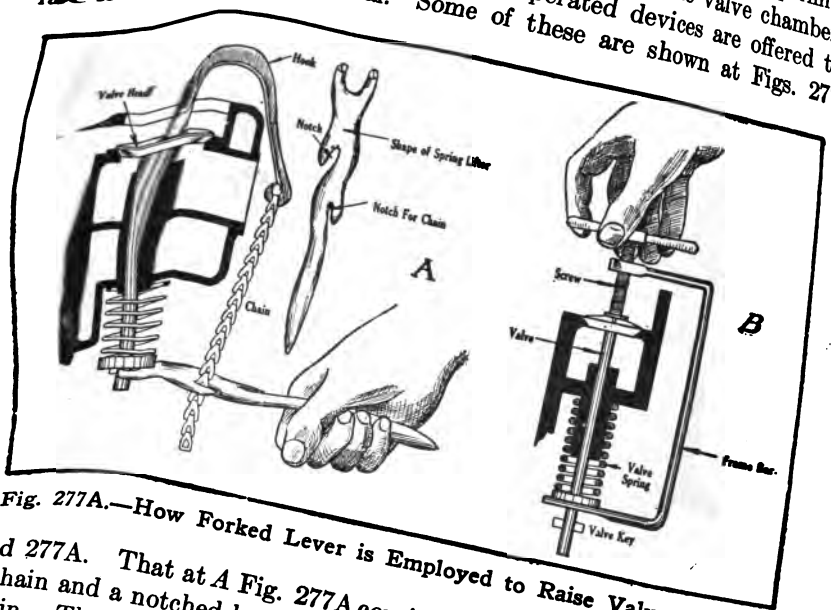


Fig. 277A.—How Forked Lever is Employed to Raise Valve Spring.

and 277A. That at *A* Fig. 277A consists of a simple hook carrying a chain and a notched lever which is adapted to fit the links of the chain. The method of using is so clearly shown in illustration that explanation of its action is almost unnecessary. The function of the hook member is to hold the valve head down against its seat while the spring is compressed by the spring lifting lever placed under the collar at the lower end of the valve stem. By bearing down on the long arm of the lever the collar and the spring which rests against it is easily raised and the key may be withdrawn from

the stem. The form shown at *B* is equally simple in its application and consists of a frame bar having a screw at the upper end and a fork at the lower end. By turning the hand screw the valve spring may be compressed with but little exertion and the valve key removed. The form shown at Fig. 277 is a simple fulcrumed lever carried by an adjustable support that permits raising the valve spring though some method of holding the valve head down against the seat must be used in combination with this tool. The usual method is to interpose a block of wood between the valve head and the valve chamber cap while the spring is being compressed to permit one to remove the keys.

Q. Enumerate principal valve defects.

A. The exhaust valves usually suffer more than the intake members because they are constantly exposed to the corroding effect of the hot exhaust gases. Exhaust valve heads will warp and the seats will be scored or pitted sooner than inlet valves. Sometimes the valve head may flake and these particles of metal will get between the valve and seat and keep the head from seating correctly. Inlet valves are not so apt to warp as the exhaust valves because they are exposed to the comparatively cool charges of gas coming from carburetor. Some valves are made with cast iron heads riveted to a steel stem. These very often give trouble because the heads will crack or break or may become loose on the stem. Valve stems are sometimes bent or they may become gummed in the guides so they do not move freely. The principal valve trouble is defective seating due to wear between the valve head and the valve seat and is generally easily remedied by grinding the valves to a new seating.

Q. Outline process of valve grinding.

A. Valve grinding is a simple process, though it must be carried on carefully in order to secure good results. The valve heads of most cars will be provided either with two small holes, as shown at *A*, Fig. 278, or with a screw driver slot, as shown at *B*, Fig. 278. Tools may be made to fit the valve head at one end and the ordinary form of carpenters' bitstock at the other. The process of valve grinding itself consists of coating the valve and seat with some

abrasive compound, usually fine emery, ground glass or carborundum dust and oil mixed to a paste. A coil spring is placed under the valve head, as indicated at Fig. 278-C in order that the valve will be raised from its seat whenever the pressure on the bit stock is released. A plug of waste or cloth is placed in the passage between the valve chamber and the cylinder in order to prevent the abrasive compound from working into the cylinder. The valve is turned a portion of a revolution and back again by means of the grinding tool and bitstock and new abrasive material is added from

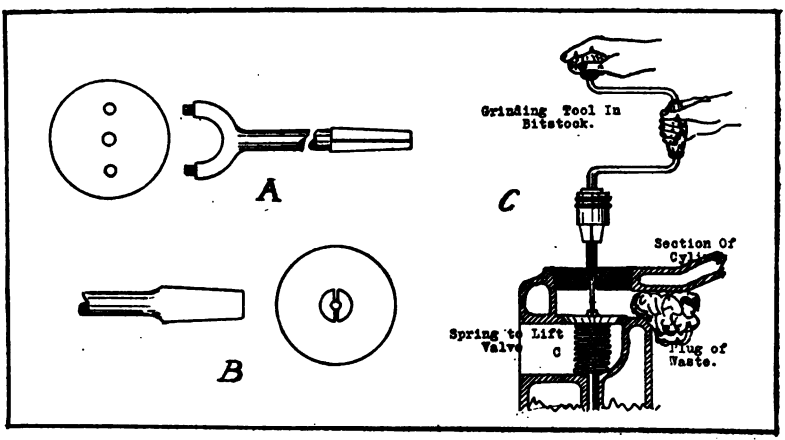


Fig. 278.—Method of Grinding Motor Car Engine Valves to Correct Seating Which Insures Proper Compression of Gas Prior to Ignition.

time to time. The valve is removed and both valve head and seat washed thoroughly with gasoline in order that the condition of the surfaces be easily determined. When both valve head and seat are bright and without scores, ridges, pits or other depressions it is reasonable to assume that the valve has been ground in properly. Very little pressure is needed to hold the valve against the seat while grinding. In fact the weight of the bitstock is usually sufficient. It is better to use an oscillating motion rather than turn the valve completely around while grinding.

Q. How can one tell if valves are seating correctly after grinding?

A. The fit of the valve head and the valve seat is usually tested by coating the valve head with Prussian blue pigment and pressing it in place against the seat. The valve is then turned about one-fourth of a revolution and removed. If the valve and seat are a proper fit, the entire seat will show blue, though if the valve head and seat do not fit only the high spots or ridges on the valve seat will receive a coating of blue. In such an event the grinding process should be continued until the valve head has an even bearing all over on the seat.

Q. Outline the two common conditions that will prevent valves seating, even if they fit properly.

A. A particle of foreign matter or carbonaceous material between the valve head and seat will keep the valve from closing properly as will also lack of clearance between the valve operating plunger and the valve stem. A broken valve spring may also prevent a valve from seating properly. Weak valve springs also make the valves tardy in closing.

Q. What should next be examined if valve grinding does not improve compression?

A. The piston rings, piston and cylinder walls are the next points that demand attention if grinding the valves does not suffice to make the cylinder gastight.

Q. What are the principal piston ring troubles?

A. Piston rings may have worn so they are a very loose fit in their slots or they may be gummed up with oil or carbon deposits so they do not move freely. The rings may also be broken or they may have worked around so all the slots are in line. Piston rings may also lose their elasticity and not form a proper packing.

Q. How are piston rings removed?

A. Piston rings may be removed from the piston as shown at *A*, Fig. 279. Three thin strips of metal are needed; these may be and often are made of hacksaw blades with the teeth ground off or strips of tinned sheet iron or old clock spring. The ring is spread

either with a pair of special pliers made for the purpose or by inserting a screw driver between the ring and the piston and the metal strips are put in place as indicated. This brings the ring entirely out of the groove in the piston and makes possible the easy removal of that member without danger of breaking. A reversal of this process will enable one to replace the piston rings just as easily as they are removed. When removing the rings one should start with the top one, whereas when replacing them the bottom ring is the first to go on.

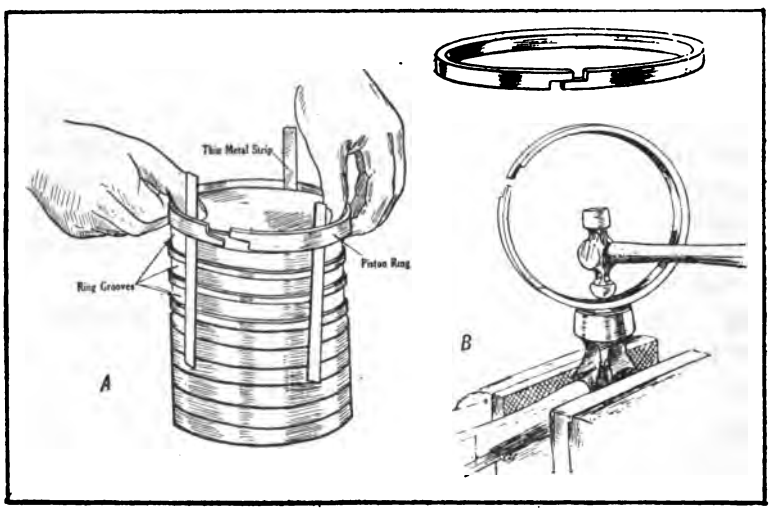


Fig. 279.—Showing Method of Removing and Peening Piston Rings.

Q. How can piston ring troubles be eliminated?

A. If the piston rings are worn or broken the best method of repair is to replace the ring with new members which must be carefully fitted so that they will move freely in the piston grooves and at the same time care should be taken that they will fit the cylinder interior. If the grooves are filled with gummed oil or carbon they should be cleaned out thoroughly before the rings are replaced. Rings that have lost their elasticity are sometimes restored to a proper condition by a process known as "peening." This is clearly

shown at Fig. 279-B. It consists of delivering a series of blows with a light ball peen hammer around the interior of the ring while the face bears against some absolutely smooth steel member. Care should be taken in hammering the ring that the blows are light because cast iron is a very brittle material and will break easily. The strength of the blows should be varied according to the thickness of the rings. Heavier blows are struck at the thick portion of an eccentric ring and these gradually become less in force the nearer they are applied to the thin end.

Q. Is cylinder or piston wall ever at fault?

A. Poor compression is often caused by deep scratches or grooves on cylinder and piston walls. The gas leaks by the rings no matter how well these fit the cylinder because they can only serve to make a cylinder gastight when the bore is smooth and practically round.

Q. What is the main cause of deep grooves in cylinder?

A. The most frequent condition resulting in deep grooves in the cylinder wall is a failure of the wrist pin fastenings, as these sometimes come loose and permit the hardened steel wrist pin to bear against the soft cast iron walls of the cylinder. The sharp edge of the wrist pin acts as a cutting tool despite the presence of lubrication and a deep groove will eventually be worn in the cylinder on account of the rapid reciprocation of the piston while the engine is in operation. It is practically impossible to restore a cylinder that has been deeply grooved by a wrist pin. The most practical way of restoring the engine to its full efficiency is to replace the defective cylinder member.

Q. What causes fine scratches on piston and cylinder wall?

A. If lubrication is deficient, such as when unsuitable oil is used or when the lubricant is not supplied in proper quantities, the piston is apt to cut the cylinder and the result is that both surfaces in contact are covered with a series of fine scratches. While these are not as deep as those caused by a loose wrist pin, still they may have sufficient depth to permit considerable gas to leak by. Fine scratches may often be eliminated by grinding out a cylinder to a slightly larger size and fitting new piston and piston rings.

Q. Describe formation of carbon deposits and how they affect the action of the motor.

A. If oil of low fire test or too much of the proper oil is used the excess lubricant will burn in the combustion chamber and while the heat will vaporize the volatile constituents a certain amount of solid matter, which is practically pure carbon, will be deposited on the top of the piston and the cylinder head and around the valves. These deposits are also augmented by road dust and other foreign matter taken in through the carburetor. If the mixture is too rich, the excessive fuel used will also deposit carbon.

An engine in which the carbon deposits are excessive is apt to overheat readily, lose power and knock just as though a bearing were loose. The condition of the interior of the cylinder may be easily ascertained by removing a spark plug or valve chamber cap which permits one to examine the interior of the combustion chamber.

Q. How is carbon removed from combustion chamber?

A. In some types of engines, such as used on the Ford, the Metz, and Maxwell "25," it is possible to remove the entire cylinder head members to expose the pistons and valves as well as the interior of the combustion chambers. The carbon may be easily removed by softening with kerosene, wood alcohol, acetone or similar carbon solvents. The deposits are then easily removed by means of scrapers made especially for the purpose. In other forms of engines, notably of the T head type, having large valves, it is possible to scrape out most of the carbon by removing the valve caps and using scrapers shaped like small hoes. Carbon deposits may also be burned out with an oxygen flame.

On other engines in which the piston rings are a good fit it is possible to soften most of the carbon by using some liquid carbon remover which is introduced into the combustion chamber by means of a squirt gun. This loosens up the carbon and after the carbon remover is taken out of the cylinder again the engine may be started up and the loose carbon will be blown out through the exhaust valve. The surest method of removing this material is to take the engine apart sufficiently so that the members affected may be reach-

ed easily and the carbon removed by positive mechanical means. A simple preventive of carbon deposits is to put in a tablespoonfull of kerosene in each cylinder through the compression relief cocks at the end of a day's run while the engine is still hot. This will soften up the carbon over night and when the motor is started the next day a large proportion of the carbon deposited the previous day will be blown out with the exhaust gases.

Q. What are the three main causes of skipping?

A. Skipping or irregular engine operation which results when one or more of the cylinders does not fire regularly may be due to defects existing in the engine itself, notably in the valve system; faulty ignition or defective carburetion.

Q. Describe defects of valve system that may cause misfiring.

A. If the inlet or exhaust valves do not seat properly or fail to open and close at the right time the action of the engine will be irregular. One of the main troubles is defective valve seating. This may be caused by a worn, scored or pitted valve head and seat; by a warped valve head, foreign matter under the valve, a weak or broken valve spring or lack of clearance between the end of the valve stem and the operating plunger or tappet rod. A stuck or bent valve stem or one that has become so covered with scale that it sticks in its guide bushing will also prevent smooth engine operation. The conditions that will cause the valve to loose the proper timing are, insufficient or too much clearance between the valve operating plunger and valve stem, wear in valve operating mechanism, such as on cam profiles and cam rolls, and wrong meshing of the timing gear on the camshaft with that on the crankshaft. On some engines the cams are separate members pinned or keyed to the camshaft and if these methods of fastening fail the engine timing will be disturbed. A sprung camshaft has also been known to cause irregular engine operation.

Q. Outline main troubles in ignition systems.

A. The main trouble in the average ignition system is faulty spark plug action. Sometimes the source of current or the wiring

may be at fault and again the trouble may exist in the switch and commutating or current distributing apparatus.

Q. Describe steps in locating ignition troubles when a vibrator coil system is used.

A. A typical simple ignition system which consists of a four unit vibrator coil supplied with current by a magneto integral with the motor flywheel is outlined at Fig. 280. The current from the magneto is distributed by a timer located at the front end of

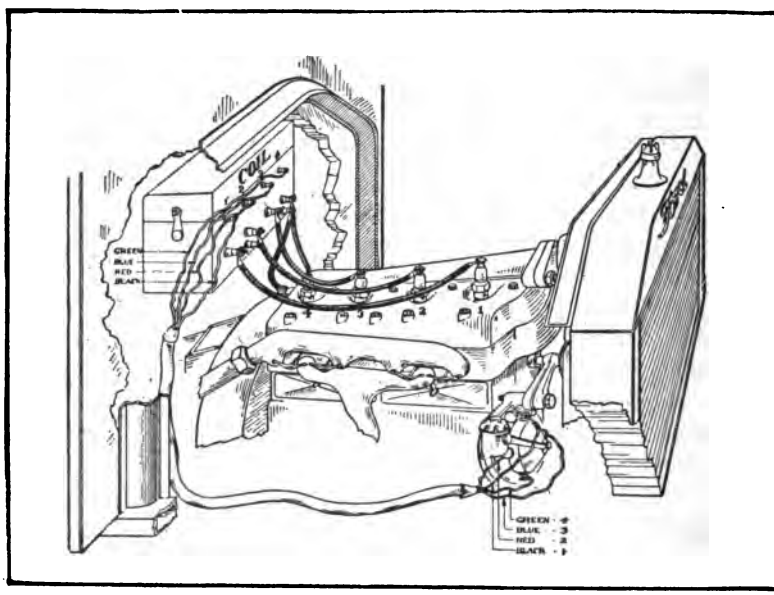


Fig. 280.—Wiring Diagram of Ignition System of Ford Cars.

the engine on an extension of the camshaft. Four wires lead from this device to the various coil units. Four secondary wires lead from the coil to the spark plugs in the cylinders. The first thing to determine if the engine is not running regularly is which cylinder or cylinders are not firing regularly. This may be easily accomplished by removing the cover of the coil box, speeding up the engine slightly by opening the throttle and then holding down three of the vibrators so the engine will run on only one cylinder.

Each of the cylinders is tried in turn by holding down the vibrators of all the other three cylinders. The engine will stop when the cylinder that is not firing is reached. The spark plugs are the first thing to be looked at provided that the coil vibrator is buzzing all right. If the coil vibrator is not buzzing the first thing to look at is to make sure that the contact points between vibrator spring and fixed contact members make a proper electrical connection. Then the wire leading from the coil that does not operate to the timer should receive attention. It is imperative that the terminals be tight at both coil box and timer, that the insulation be whole and not in contact with any metal. The timer should also be examined to see if the contact brush or roller is establishing the proper connection between the segments spaced around the inner periphery of the fiber ring.

Q. If batteries are used for current supply, how are these members tested?

A. The amount of current delivered by batteries may be measured by using an ammeter for dry batteries and a voltmeter for storage batteries. Dry cells should indicate over eight amperes each whereas a storage battery should indicate not less than six volts if it is a three cell type commonly used for ignition purposes.

Q. Outline commutator or timer defects.

A. The main cause of trouble in a primary timer is deposits of oil which have been impregnated with metal particles due to the abrasion between the contact brush or roll and the insulated metal segments. The roll that establishes contact may be worn unduly on its bearings or the spring that holds the roll against the segments may be weak or broken. If the contact segments are pitted or roughened by the action of the current the timer should be placed in a lathe and the interior ground out smoothly in order that the surfaces of the contact segments be on a true surface and be bright and clean. If the path of the roller is irregular, i. e., if there are alternate depressions and high spots, the action of the timer will be erratic at high engine speeds though ignition will be regular

enough at low speeds. Some forms of timers use a touch contact between platinum points instead of a wipe contact. Any timer employing platinum points must not only be carefully adjusted but must be kept entirely free of oil particles.

Q. Name spark plug faults.

A. The most common defect of spark plugs and the easiest to remedy is short circuiting by means of oil or carbon deposits. To restore the plug to full efficiency it is necessary to remove the offend-

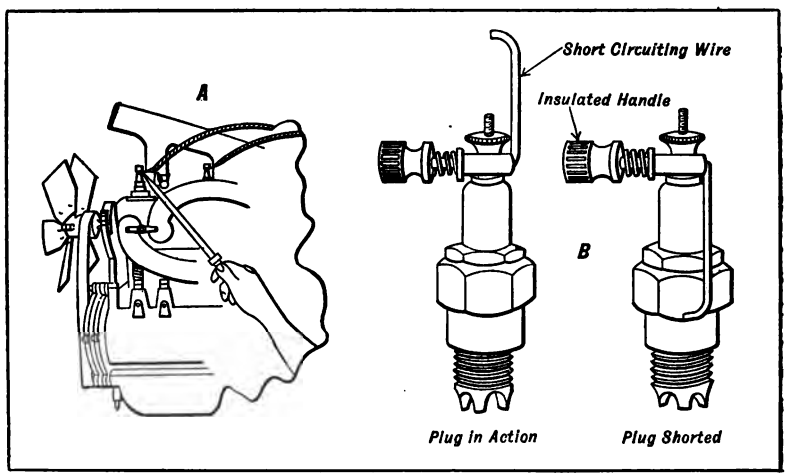


Fig. 281.—How to Short-Circuit Spark Plugs to Detect Cylinder That is Not Firing.

ing foreign matter and clean the surfaces of the insulator as well as brightening the spark plug points. Sometimes the insulator becomes oil-soaked or cracked and allows the current to short circuit to the metal bushings instead of jumping the air gap between the points. The space between the spark plug points may not be correct, if there is too much of an air gap the spark will not overcome the resistance of the compressed gas whereas if the points are too close together the spark will not have sufficient heating value to ignite the charge.

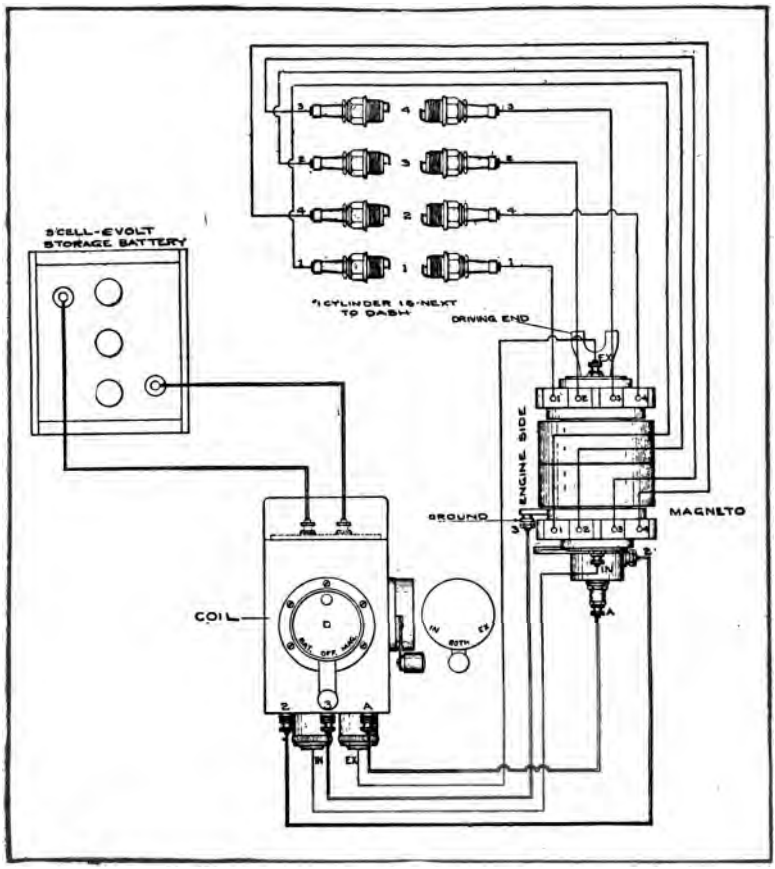


Fig. 282.—Double Ignition System Showing Wiring For Both Battery and Magneto and All Parts to Be Inspected in Event of Ignition Trouble.

Q. Describe principal induction coil troubles.

A. The main induction coil trouble is defective vibrator action. This is commonly caused by the platinum contact points becoming pitted or burnt so that proper electrical contact is not established. If the points are burnt, the vibrator will cause trouble at low and high speeds, whereas if they are pitted, the vibrator is apt to stick at high speed. The contact points should be carefully smooth-

ed with a very fine file or oil stone and the vibrator must be carefully readjusted. The vibration should be rapid enough so a distinct buzzing sound is produced. Another cause of poor induction coil action is broken wires or loose terminals. Sometimes internal defects, such as a burnt out condenser or a punctured secondary winding, will cause trouble. Defects of this nature can be fixed only by the maker of the coil or an electrician having suitable equipment.

Q. How can missing cylinder be found when a high tension magneto is employed?

A. It is not possible to locate missing cylinders by means of holding down the vibrators on the coil when a magneto is used so it is necessary to short circuit the plugs to determine which are at fault.

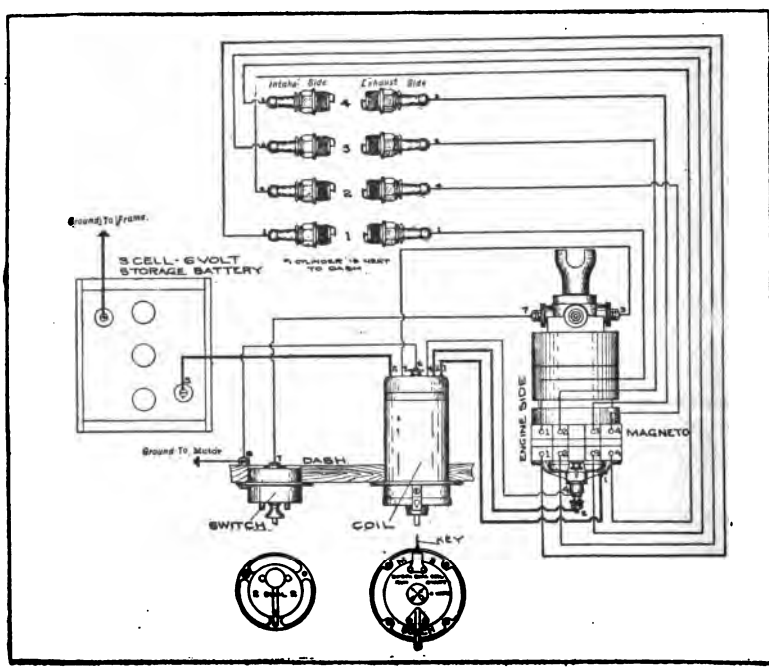


Fig. 283.—Parts of Bosch Dual Ignition System and How Wired Together.

The method outlined at Fig. 281-A is that commonly followed. A screw driver or similar tool having a wooden handle is brought in contact with some metal portion of the engine and almost touched to the insulated terminal on the spark plug. If the spark is delivered from the magneto distributor it will jump the gap between the screw driver point and the spark plug terminal rather than jump the spark gap in the cylinder. Each of the spark plugs may be tested in turn and if the current reaches the plugs it will indicate this fact by sparking between the screw driver blade and the plug terminal. After all the plugs have been tested in this manner and the current is found to flow from the magneto as it should the next thing to do is to locate the missing cylinder. This is done by short circuiting each of the plugs in turn with a screw driver blade by establishing a direct metallic contact between the insulated terminals and the engine. If the engine is running on three cylinders, there will be a difference noted in the operation of the motor when any one of the three good plugs is short circuited. If short circuiting the remaining plug does not seem to interfere with engine action it is reasonable to assume that this member is the one at fault, and it should be removed for inspection, cleaning or readjustment. A simple short circuiting device that can be applied to any conventional spark plug is shown at Fig. 281-B. This consists of a short circuiting wire attached to the top terminal that may be brought down by means of an insulated handle so it establishes a metal connection between the two portions of the plug.

Q. Name magneto faults and tell how to remedy them.

A. The principal trouble in a high tension magneto is dirt in the distributor or contact breaker. The contact breaker of the Bosch high tension magneto is shown at Fig. 284. The main point to observe is that the interior of the device is clean, that the contact points separate when the fiber block rides on a steel segment and that they contact at other times. The contact points must not only be clean and establish the proper electrical contact but they must also be properly adjusted. A thin sheet metal gauge is usually furnished by the magneto manufacturer to indicate the proper gap that should exist between the points when the fiber block rides on the steel segment. The gap between the points may be regulated

by means of the adjusting screw provided. If the contact points do not separate it is because the fiber block at one end of the interruptor or bell-crank lever is worn so that it rides over the surface of the steel segment or cam without producing separation of the contact points.

The parts of a Splitdorf magneto are clearly outlined at Fig. 285. In addition to the contact breaker faults previously enumerated one should examine the secondary distributor to see that the interior is perfectly clean and entirely free from oil, metal or carbon particles. The collecting brushes and the distributing member should project far enough out and be kept there by a spring of

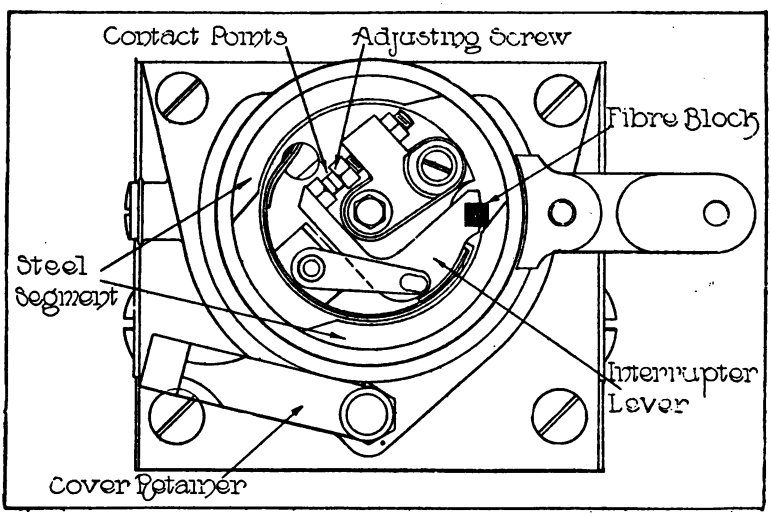


Fig. 284.—Contact Breaker of Bosch Magneto Showing Means of Adjusting Contact Points.

sufficient strength so that they will contact positively with the distributing segment carried on the face of the fiber plate attached to the distributor gear. Collecting brushes are also used on some forms of magneto to deliver the current from the armature to the distributor, or to external apparatus, such as an induction coil. These brushes should make a positive contact with the collecting ring and should not only be free from oil but move easily in their

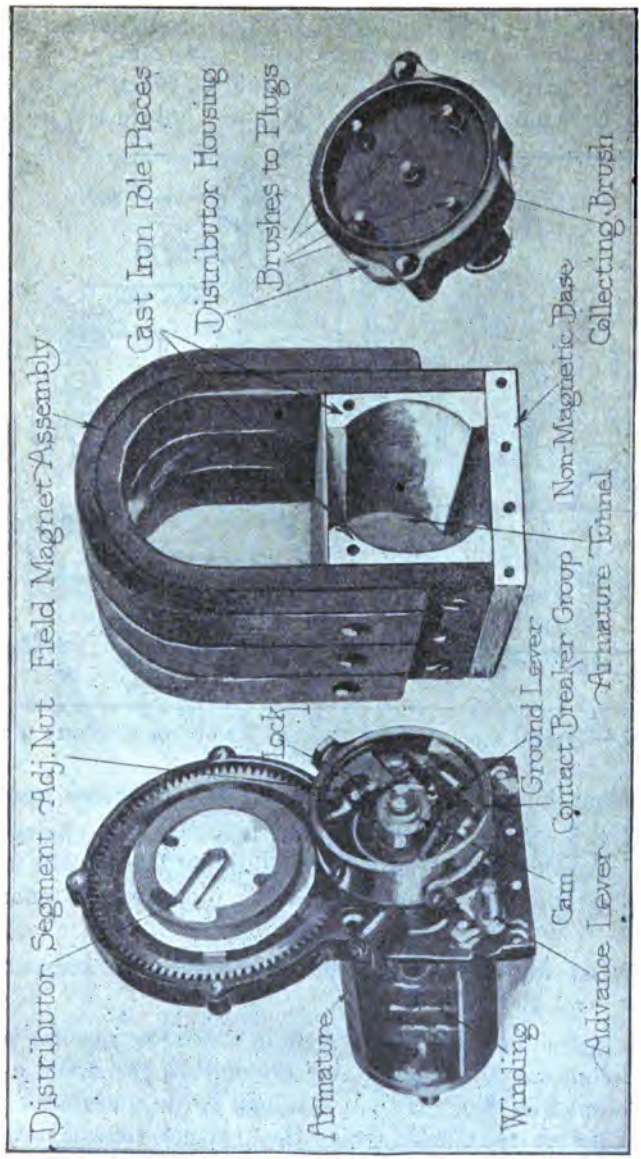


Fig. 285.—Parts of Splitdorf Magneto for Four Cylinder Ignition Showing Points Demanding Attention in Event of Ignition Trouble.

sockets. Magneto field energizing magnets sometimes lose their strength but this is not a common fault. They may be easily re-energized by any electrician. Care should be taken not to use too much oil in a magneto because it is apt to injure the insulation.

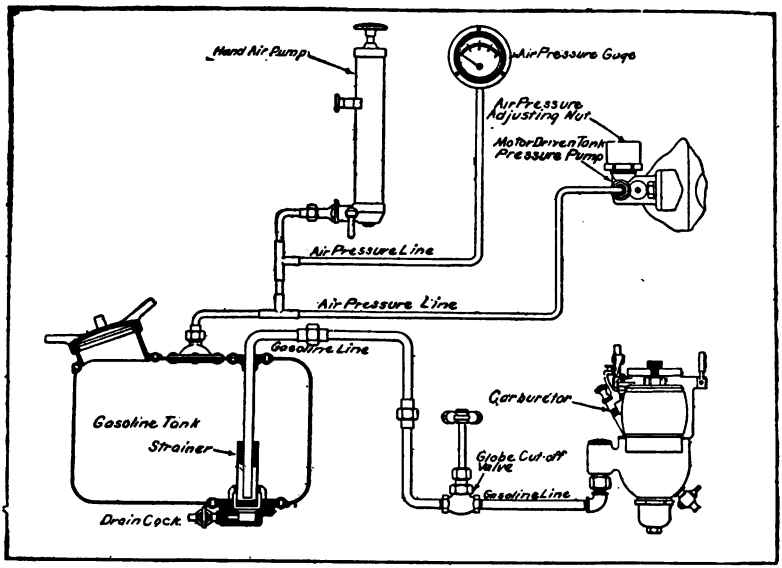


Fig. 286.—Typical Fuel Supply System Involving Pressure Feed of Gasoline.

Q. What faults of the carburetor cause irregular operation?

A. If the mixture is not properly adjusted the engine is apt to work irregularly and any carburetor faults that will interfere with the proper proportion of gaseous mixtures will cause misfiring.

Q. What faults may prevent fuel supply in pressure feed system?

A. A typical pressure feed system in which the gasoline is forced to the carburetor by means of air pressure in the main container is outlined at Fig. 286. If there is a leak in the container or piping that will permit the air to escape the carburetor will not receive gasoline. As this condition may be easily determined by watch-

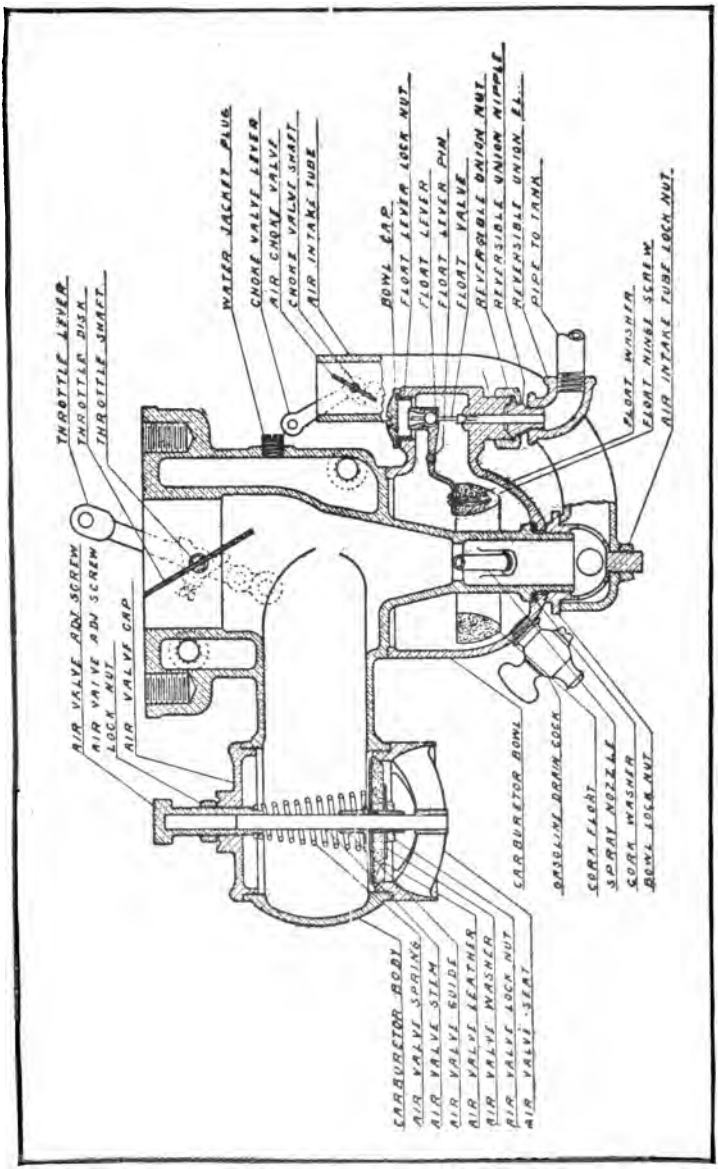


Fig. 287.—Sectional View of Schebler Carburetor Showing Mixing Chamber and Float Bowl Parts.

ing the air pressure gauge on the dash it is not difficult to determine if the defective fuel feed is caused by lack of air pressure or an obstruction in the piping leading from the tank to the carburetor. The point at which leakage is more often found is at the filler cap which may not be properly screwed down after the tank has been filled. Sometimes the motor driven air pressure pump will fail but this condition is readily noted by a drop in pressure at the gauge and the

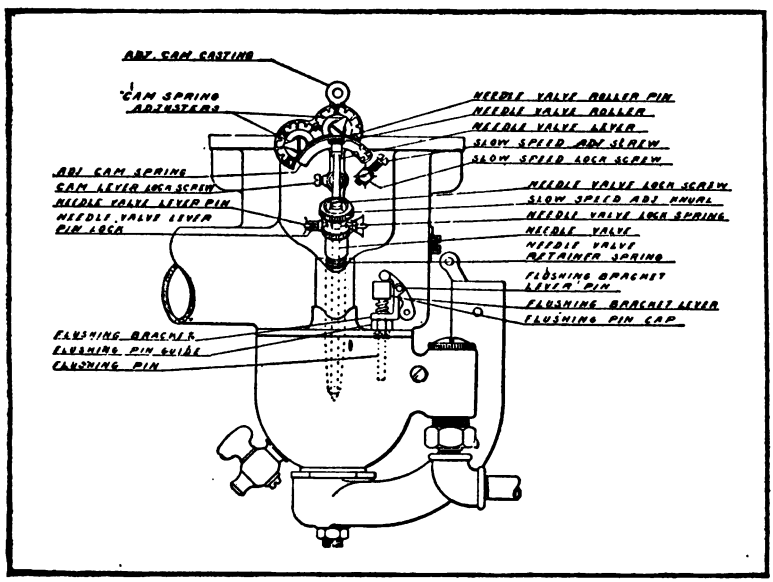


Fig. 288.—Exterior View of Schebler Carburetor Showing Means for Varying Mixture Adjustment.

auxiliary hand air pump may be brought into play to supply gasoline to the carburetor until the power air pump may be examined. The common trouble with an air pump, provided that the plunger or cylinder is not worn too much, can be traced to defective operation of inlet and discharge check valves.

Q. Name principal mixing chamber troubles.

A. The principal mixing chamber defects are constricted spray nozzle or defective auxiliary air valve operation. If the air valve is closed down too tightly so it does not rise enough the mixture

is apt to be excessively rich, whereas if it opens too much the mixture will have a surplus of air and it will be slow burning and cause "popping back" in the carburetor. The cross section of the Schebler carburetor, outlined at Fig. 287, clearly shows the construction of a typical auxiliary air valve and the location of the gasoline spray nozzle. The external view at Fig. 288 shows the various adjustments of this carburetor. A sectional view of the Stromberg device is shown at Fig. 289.

Q. Outline main float bowl defects.

A. If the gasoline level in the float chamber is too high it will overflow at the spray nozzle and produce an excessively rich mixture. This may be caused either by poor adjustment of the float, by foreign matter between the float operated shut-off valve and its seat or by alteration in the weight of the float. If the float is of cork it may become saturated with fuel, whereas if of metal it may leak and admit fuel to its interior. If the level is too low in the spray nozzle the mixture will be too thin and motor action will be erratic. This condition is caused mainly by poor float adjustment or the constriction of the passage through which the gasoline enters the float chamber by lint or other foreign matter.

Q. Do inlet manifolds ever cause trouble?

A. If there is an opportunity for air to leak in either through defective gaskets or through a crack or blowhole in the manifold, the mixture will not have proper proportions no matter how carefully the carburetor is adjusted and the engine will not run properly. Another opportunity for air to enter the engine and dilute the mixture is through worn inlet valve guides.

Q. What troubles in the motor cause noisy operation, and what is the nature of the noise?

A. Carbon deposits in the combustion chamber cause a dull knocking sound, worn timing gears produce a grinding noise, dry bearings or cylinder will be indicated by a squeak, leaky packings or gaskets in the combustion chamber will be denoted by a pronounced hissing noise, looseness of minor parts will be indicated by a rattle, while serious wear in the main bearings or connecting rods will be evidenced by a pronounced metallic knock.

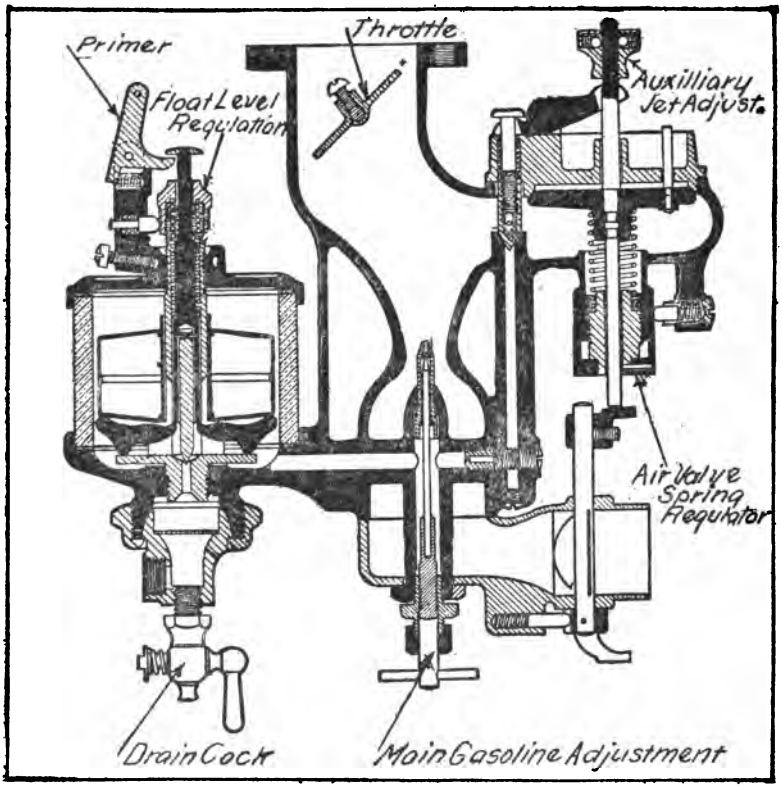


Fig. 289.—Stromberg-Winton Carburetor With Methods of Varying Mixture Adjustment Clearly Shown.

Q. How can loose main or connecting rod bearings be detected?

A. On most engines it is possible to either remove an inspection plate at the side of the crank chamber or the bottom of the crank case that will permit one to locate looseness in the bearings by feeling of them or attempting to move them up and down with a small pinch bar placed under the crankshaft to test the main bearings and under the connecting rod caps to test the crank pin bearings.

Q. How are loose bearings fixed?

A. The common method of restoring loose bearings, provided

that the wear is not abnormal, is to remove the bearing caps and take out some of the shims usually interposed between the bearing caps and the crank case portion of the main bearings, or between the members of the connecting rod bearings. When these shims are removed the bearings are brought down closer to the shaft. In order to prevent the box from bearing at only one point on the shaft it is customary to scrape the bearings to fit. The connecting rod bearings wear soonest, on account of their projected area being less than that of the main bearing, and also because they are subjected to the full force of the explosion. The upper half of the crank case of a typical four cylinder motor with the crank shaft and main bearings exposed is clearly outlined at Fig. 290.

Q. Name principal cause of poor lubrication if trouble is not in oiling system.

A. Poor lubrication may result from the use of unsuitable oil or from clogged passages or oil grooves at the bearings.

Q. Describe troubles of pressure feed oiler and gravity feed type.

A. If the oil does not reach the manifold fitting from which the pipes lead to the bearings to be lubricated, the first thing to do is to examine the oil tank to make sure that there is a proper amount of lubricant therein. The next point is to see that there are no leaks through which pressure can escape and that the check valve through which the air or exhaust gas is admitted to the oil tank is in proper working condition. If the sight feed glasses fill up it is a sure indication that oil reaches the manifold fitting but that pipes leading from the full glasses are clogged or blocked in some manner so that oil does not reach the bearing point. Sometimes there may be sufficient pressure on top of the oil in the container to cause it to flow but the oil supply pipe may be clogged up or the needle valves adjusting the flow on the manifold may not be opened enough or may be constricted by solidified oil or wax. If a sight feed oiler fills up, the pipe leading from that member to the bearing point it serves should be removed and thoroughly cleared out. Care should be taken with pressure feed oiler to use only lubricants of the proper viscosity, as heavy oils are not adapted for this system

of lubrication. Medium bodied oils may be used successfully in summer while only light oils having a low cold test should be employed in winter.

Q. Outline main troubles with mechanical oilers.

A. The simplest form of mechanical oiling system is the constant level splash feed where an oil pump circulates the oil from the sump at the bottom of the crank case to the compartments in which the connecting rods dip. The main trouble with a system of this nature is failure of the pump or pump driving means or the filter screen mesh, that insures that the pump will only take in clean oil, becomes clogged with particles of lint, carbon or other substances.

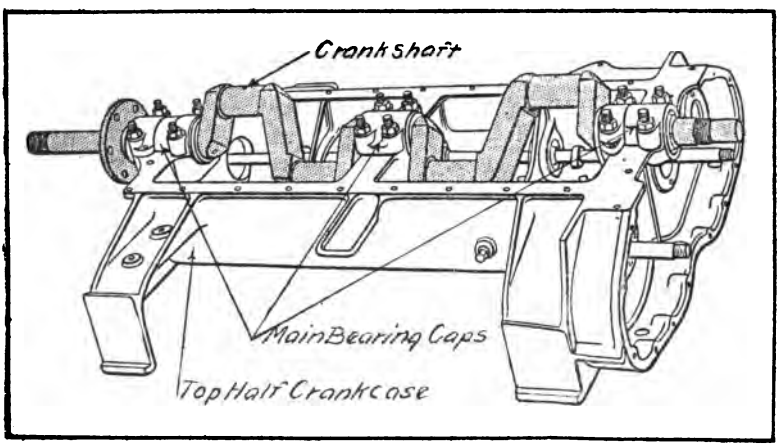


Fig. 290.—Top Half of Crankcase With Crankshaft in Place to Show Main Bearings.

As these fill the mesh of the filter screen they prevent adequate quantities of oil passing through the system. When mechanical oilers of the individual pump type are used, a failure of the entire device to supply oil may be ascribed to a defect in the driving member, whereas if only one or two leads are at fault and the rest function properly the trouble is local and is probably due to faulty action of the inlet or discharge check valves on the small pumps supplying the leads through which no oil is passing. If the trouble is not in the pumps or their check valves, the pipe leading to the bearing should be taken off and cleaned out.

Q. What are main causes of overheating when thermo-syphon cooling system is used?

A. If a motor employing a natural circulation system overheats, this condition can be ascribed more often to defective carburetion or lubrication than to poor cooling. If the trouble is due to the cooling system, practically the only thing that can occur is constricting the bore of one of the rubber hose members interposed in the pipe line, as might be possible if the inner walls of the hose deteriorated and allowed particles of rubber or fabric to hang down into the hose. Sometimes the cylinders may be full of scale or rust or the radiator tubes may be clogged with similar material. The presence of scale or rust in the interior of the water jacket is not only apt to produce heating by impeding the flow of the cooling water, but it also lowers the efficiency of the cooling system because less heat is abstracted from the cylinder wall or combustion chamber sides if these members are coated with scale that keeps the water from being directly in contact with the heated metal.

Q. What are the main defects of a pump circulating system?

A. The main cause of overheating with a forced water circulation system of cooling is failure of the pump drive or some defect in the pump itself that prevents circulation. The pipes may be filled with sediment or scale or there may be accumulations of rust or sediment in elbows or similar connections included in the pipe line. One common defect that often causes overheating with either natural or forced circulation is failure of the fan driving belt.

If the radiator tubes are filled with scale, this material may be removed by filling the radiator with some solution adapted to cut the scale. In some sections of the country, hot washing soda solution will soften the accumulations, whereas the water in other districts makes it necessary to use some dilute acid instead. If the only running water available contains matter that will form scales it will be well for the motorist to use only distilled or rain water in the cooling system.

Q. How will defective lubrication cause heat?

A. If the cooling system is at fault and proper quantities of lubricant are not supplied to the cylinders, there will be much power

absorbed in friction and wherever friction is present heat will always exist. An engine that is heating up unduly is generally one that is not lubricated properly or that is burning too rich mixture of gas if the trouble is not in the cooling system.

Q. How will defective mixture cause heat, and how is carburetor adjusted to overcome this condition?

A. A mixture that contains too much gasoline vapor will be slow burning and will have more heating value without producing correspondingly more power than one of proper proportions or having an excess of air. As combustion is not perfect, the engine will not deliver its full power and the surplus heat liberated every explosion must be absorbed by the cooling system. The carburetor adjustment varies with the type of instrument used, but as a general rule, the overheating may be reduced by either closing down the needle valve regulating the fuel supply so that less gasoline will be sprayed into the mixture or by opening the air valve to admit more air and thus dilute the rich gas.

LESSON THIRTY-THREE

TROUBLES WITH POWER TRANSMISSION PARTS

Q. What are the main clutch troubles?

A. The main clutch troubles are either harsh engagement, failure to release promptly, or slipping which means that the clutch will not transmit the full power of the engine.

Q. What is the main cause of slipping?

A. If a clutch is a cone type, as shown at Fig. 291, failure to drive properly is often due to a defective leather facing which may be either oil soaked so that it slips or glazed over so it does not have the proper amount of frictional adhesion with the female member. The spring holding the parts in contact may be weak or broken or the spring tension adjustment may have jarred loose and unscrewed so the spring does not exert sufficient pressure to keep the parts in proper frictional contact.

Q. What is the reason for harsh engagement?

A. If the clutch leather is dry or charred the clutch is apt to engage suddenly.

Q. What can be done to make the cone clutch engage easily?

A. If the leather facing is charred or worn too much it should be replaced with a new one, whereas if it has only become dry it may be softened by applying kerosene, neatsfoot or castor oil to the leather facing to soften it. Sometimes harsh engagement is due to defective or imperfect clutch design in which case it can only be eliminated by changing the clutch structure in some manner so that springs may be inserted under the leather or cork inserts may be applied in a clutch cone.

Q. What is an emergency treatment for slipping cone clutch?

A. If a clutch is slipping because of too much oil between leather facings and flywheel, the surplus lubricant may be absorbed

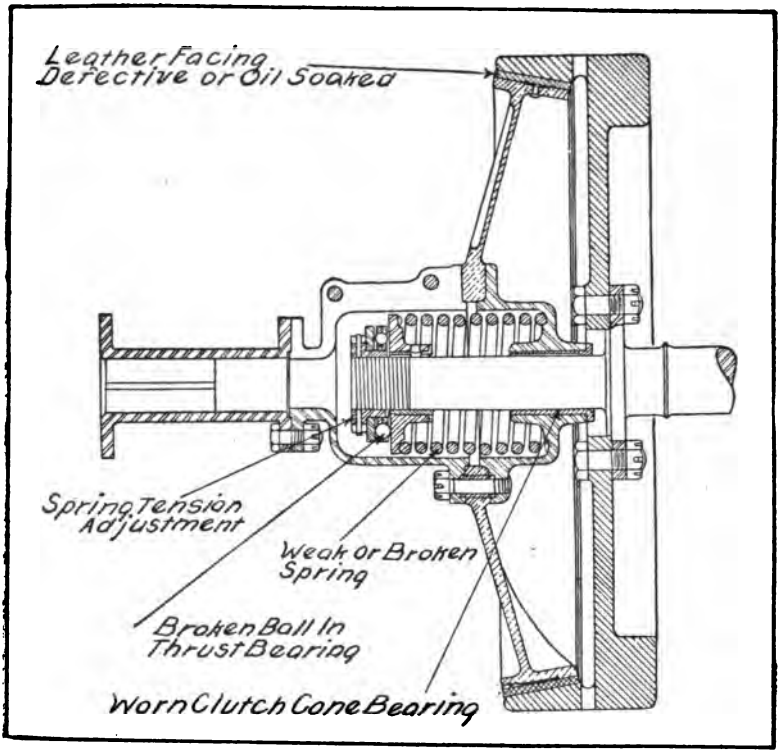

Leather Facing Defective or Oil Soaked
Spring Tension Adjustment
Weak or Broken Spring
Broken Ball In Thrust Bearing
Worn Clutch Cone Bearing

Fig. 291.—Sectional View of Typical Leather-Faced Cone Clutch Showing Points Where Deterioration Will Interfere With Proper Clutch Operation.

by fuller's earth, talcum powder such as used for tires, or borax. Sand or gravel from the road should never be used because these substances are apt to cut the leather facing or destroy the smooth finish of a cast iron member.

Q. What should be done if a clutch fails to drive properly?

A. The first thing to look at is the condition of the leather surfaces and these should be brought to proper condition before anything else is done. The leather should be soft, springy and yet not too oily. If it is burnt or charred or glazed over, slipping is unavoidable. The clutch spring and fastenings should then be

examined, and if there is a clutch and brake interlock the various levers comprising this assembly should be examined to see that they are in proper adjustment and not holding the cone out of engagement.

Q. What can be done if clutch spring is weak?

A. In almost all clutches means are provided for increasing the tension of a clutch spring if desired. If that member has weakened, it should be compressed more tightly by means of the adjustable member or members provided for that purpose. If adjustment does not produce positive driving, then the spring should be replaced with a member of proper strength.

Q. If a cone clutch does not disengage, where should trouble be looked for?

A. The first thing to examine is the clutch operating pedal and the various members by which it is connected to the clutch shifting yoke. There may be enough lost motion at the various connections so that a full sweep of the pedal does not produce full movement of the clutch cone. If the clutch actuating levers operate properly the next point to examine is the ball thrust bearing taking the spring pressure. If there is a broken ball or if it is gummed up with old dried grease the tendency of the clutch spring will be to drive the clutch cone even if that member is not in engagement with the flywheel. There will be sufficient friction at the thrust bearing if that member does not function properly so that it will turn with the engine shaft and its motion will be transferred through the spring to the clutch cone. The bearing that supports the clutch cone may wear enough so the cone will drop far enough to drag at its lower portion even when released. This also will prevent prompt disengagement. Sometimes the clutch cone bearing becomes dry and will seize on the shaft. If much friction exists between the shaft and the clutch cone bearing the cone will be carried around by the adhesion between these members and while it may not stick tightly enough to drive the car it will continue to rotate long enough after the spring pressure is released so that gear shifting will be difficult.

Q. What are principal troubles with multiple disc clutches?

A. A typical multiple disc clutch assembly is shown at Fig. 292. This form of clutch is subject to the same derangements that the cone clutch is heir to, i. e., it may slip and not transmit power effectively, it may fail to release or it may engage harshly. As has been explained in a previous lesson, multiple disc clutches are in two forms, those designed to operate without lubrication and other forms in which lubricant is necessary. If the surfaces of a clutch of the dry plate form become coated with lubricant it will slip and will not transmit its power effectively. At the other hand, if the surfaces of a type designed to run in oil get dry the clutch will not only engage harshly but will drag and fail to release promptly.

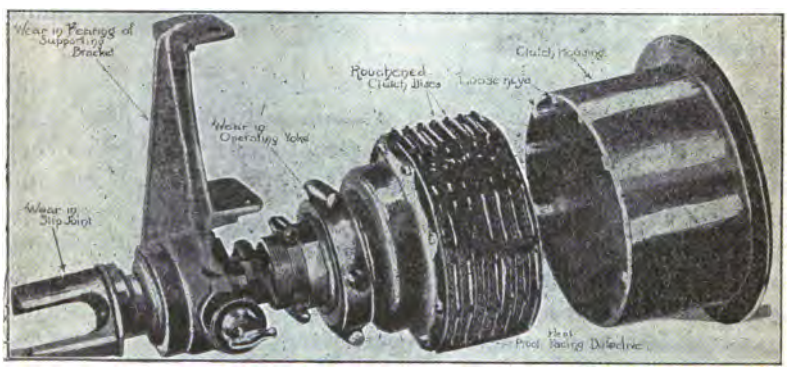


Fig. 292.—Typical Multiple Disc Clutch of the Dry Plate Type.

If a dry plate clutch engages too suddenly, the friction surfaces or the clutch disc should be examined to make sure that they are in proper condition. If the clutch plates are faced with some friction material, any defect in that member will cause trouble just as in a cone clutch. If the friction facing becomes charred or glazed over it will engage harshly whereas if it becomes soaked with oil it is apt to slip.

Q. How can clutch "spinning" be prevented?

A. Continued rotation of the driven clutch member, such as the cone or driven plate assembly, when foot lever is depressed and

clutch is supposed to be out of action may be eliminated by overcoming the defective condition producing this, such as restoring the ball thrust bearing or bearing on which the cone rotates if these produce drag; by smoothing the friction surfaces of an all metal clutch or cleaning out the charred or thickened lubricant if that is at fault. If the trouble is inherent with the clutch design employed, then some simple form of clutch brake may be fitted as previously described.

Q. Why is it undesirable to have "spinning" clutch?

A. If the clutch does not release promptly and the driven member continues to rotate when pedal is depressed it will be difficult to shift gears promptly and quietly. The clashing of the teeth produces rapid depreciation of the driving gears and the gearset is noisy all the time it is in use.

Q. What causes "friction" transmission to slip?

A. The slipping of friction disc drive is often due to accumulations of lubricant on the face of the driving wheel. This reduces the friction adhesion and even the full pressure exerted at the actuating pedal may not be sufficient to insure positive drive under severe conditions of operation. The surplus lubricant may be washed off the aluminum driving surface with gasoline and the cleaned surface may be dusted over with talc or fuller's earth to absorb any lubricant not cut by the gasoline. If slipping is not due to oily driving surfaces, it is caused by wear. After a time the friction facing on the driven wheel, which is usually a ring of strawboard fiber, becomes broomed out and will not contact properly with the driving wheel. This condition is apt to materialize if too much pressure is exerted against the pedal for ordinary driving, but it is inevitable even if extreme care is taken in operating though not apt to become serious for 2,500 to 3,000 miles. The rings are not expensive and are easily replaced. If the surface of the driving member becomes roughened or scored it will not be possible for the fiber ring to bear evenly its full width so its capacity will be reduced in proportion to the decrease in effective bearing face. The surface of the aluminum wheel must be true and smooth and if that member has become worn so a series of uneven circular grooves

or tracks concentric with the outer periphery exist on its face, it must be put in a lathe and faced off until the bearing surface is in proper condition.

Q. Why is it necessary to have center line of cross shaft coincide with that of driving disc?

A If the bearings supporting either the cross shaft carrying the fiber faced wheel or the drive shaft to which the aluminum disc is fastened wear sufficiently to permit either member to sag, it will be difficult to keep the driven wheel in position as it will have a tendency to work to one side or the other of the aluminum wheel. In order to have the wheel stay in place it will be necessary to adjust the bearings so the center lines of the cross shaft and drive shaft are on the same plane.

Q. What causes high speed clutch of planetary gearset to slip?

A. If the clutch actuating leverage wears, or the surfaces of the driving members wear a little, the drive will not be positive and it is necessary to adjust the plates or their actuating cone so they will be held together with more pressure. The planetary gearset shown at Fig. 293 is a type used on some early models of the Overland cars and the method of adjusting the high speed or direct drive clutch is clearly outlined and is typical of that form of gearing. The clutch fingers are carried by a spider member screwed on the hub of the clutch driver and this is locked in place by the pin *D*. To increase the pressure between the plates, the locking pin is pulled clear of depressions in the pressure plate and the spider is advanced or screwed up on the thread to bring the clutch fingers closer to the plate and when the proper position is reached, as indicated by the amount of resistance offered against locking the clutch plates together, the locking pin *D* may be pushed into the nearest hole to retain the correct adjustment. If the spider is tightened too much it will not be possible to engage the clutch, if it is too loose the clutch will slip.

Q. Suppose the low speed or reverse motion of a planetary gear does not engage, what can be done to remedy the slipping?

A. As previously explained the slow and reverse speeds in a

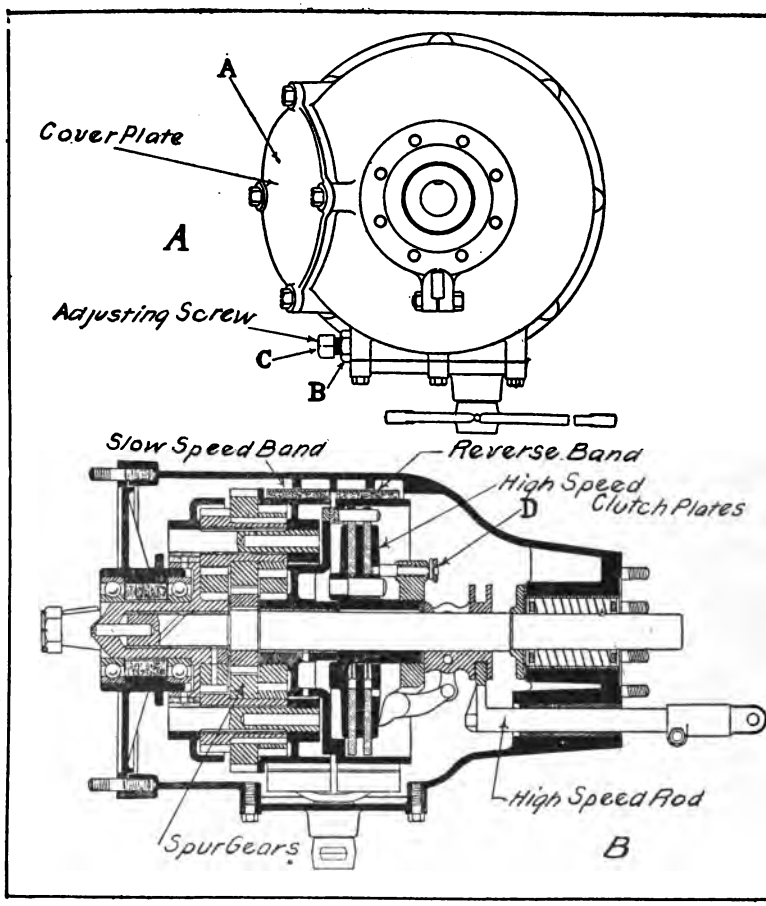


Fig. 293.—View of Planetary Change Speed Gearing Used on Some Early Models of Overland Cars Showing Points Where Adjustment Can Be Made.

planetary gearset are usually engaged by tightening a brake band around one of the drums in which the gearing is carried. In the gearset shown at Fig. 293, the band nearest the high speed clutch engages the reverse ratio while the other serves as a clutch member for the slow speed drum. Failure of these speeds to engage is generally due to slipping brake bands. In the gearset under discussion

the brake bands may be easily adjusted by releasing the lock nut *B* and screwing in the adjusting screw *C* until the band will hold in a positive manner. Two such adjusting screws are provided on the bottom of the gearcase. That nearest the front of the car serves for adjusting the reverse band, the other acts as a tightener for the slow speed band. Care should be taken not to adjust the bands so they will bind when the clutching action is not desired. If the adjusting screw is turned in to its limit and the brake band still slips it is an indication that the brake linings are worn to a point where renewal is necessary.

Q. Suppose transmission case containing planetary gearing gets hot, what does this indicate?

A. A heated planetary gear case is caused by either a slipping or binding brake band or by lack of lubricant between the bearing surfaces. The trouble is usually remedied by adjusting the brake bands so they release promptly when no pressure is applied to tighten them.

Q. What causes noisy operation of gearing on low or reverse speeds?

A. If the lubricating oil used in a planetary gearset does not have sufficient body to cushion the gear action, this form is apt to be noisy even when new. At the other hand, no matter how thoroughly one oils the gearing, any wear in gear teeth or pinion and drum bearings will produce noise which will be present at all times except when the car is on direct drive.

Q. What causes noisy operation of sliding gears?

A. A plan view of a typical four speed gearbox is shown at Fig. 294 with the points where depreciation can be expected clearly outlined. As noisy operation is due to improper meshing of gears any condition that prevents gear teeth from fitting properly will produce grinding sounds. If the bearings are worn or out of adjustment sufficiently so the main and counter shaft center lines are not in alignment it will be impossible to have correct gear engagement. If the gear teeth have become burred or battered by careless shifting, or if they have worn in service so considerable

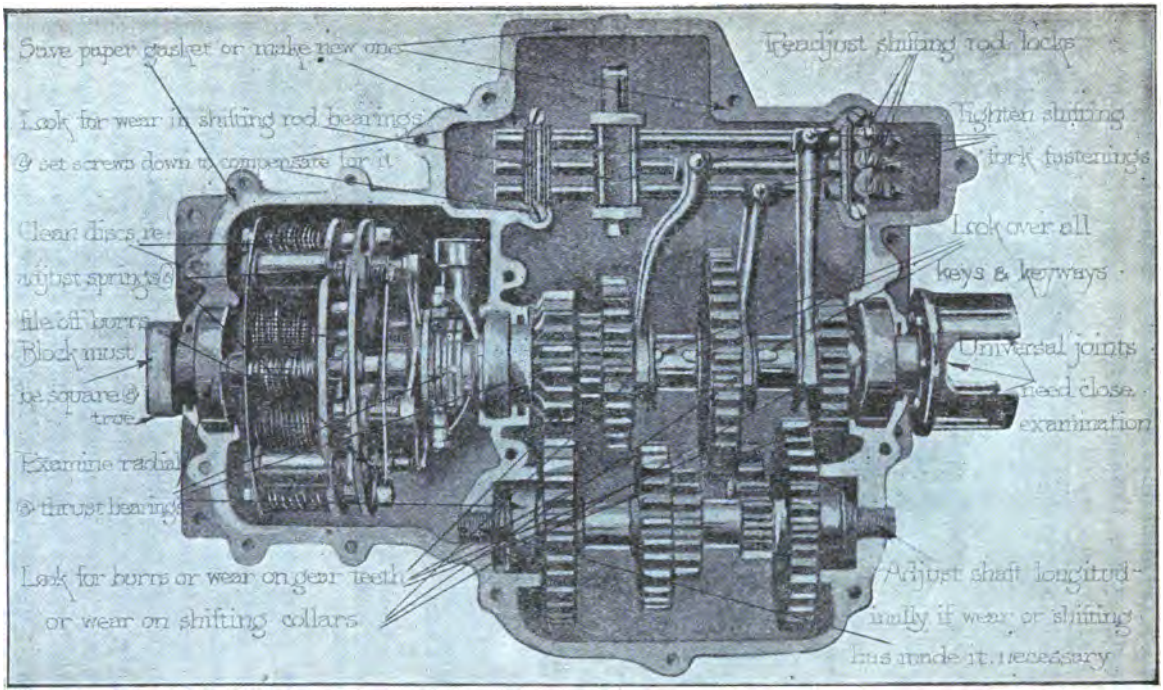


Fig. 294.—Multiple Disc Clutch and Four Speed Gear Set Assembly Showing Points to Be Examined in Event of Power Transmission Trouble.

looseness exists between the teeth, power cannot be transmitted smoothly on account of the lost motion.

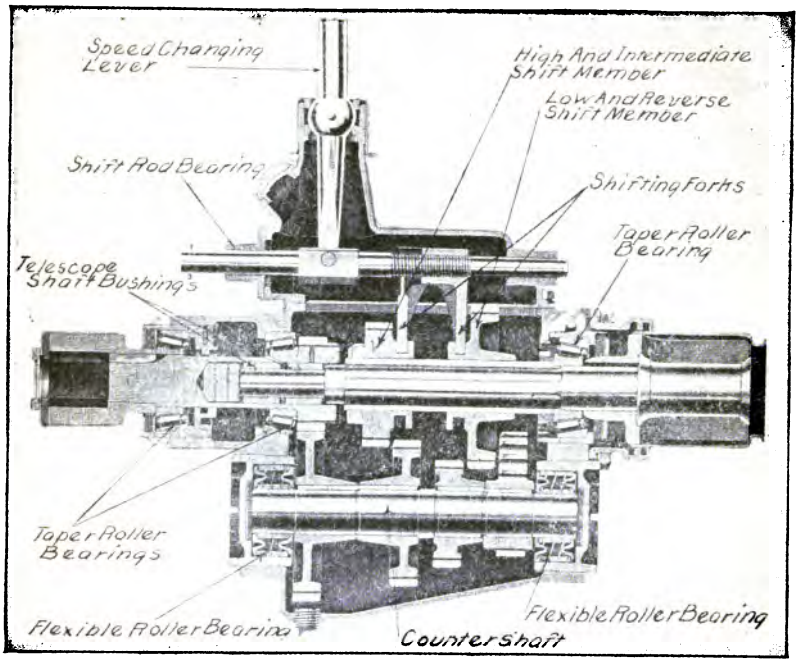


Fig. 295.—Sectional View of Reo Three Speed Selective Gear Set Showing Arrangement of Important Gears, Shift Members and Bearings.

Q. What prevents sliding gears from engaging promptly?

A. If the gear teeth are burred so that some of the displaced metal fills parts of the tooth space or if the main and counter-shaft center distances have changed through bearing depreciation or other causes it will be very difficult to engage the gear teeth promptly. Sometimes the shifter yoke actuator rods may bind in their bearings or the hand control lever employed to shift the gears may work stiffly. If the gears are in proper condition and the shaft bearings have not worn appreciably any trouble in gear shifting may be attributed to faulty clutch action.

Q. What is the chief cause of stripped gears?

A. The chief cause of broken or stripped gears, provided that these are adequately strong for the work they are to do, is attempting to shift to the gears without fully releasing the clutch. Sometimes particles of metal, such as slivers ground off of the gears when they are carelessly shifted, will get into the bearings and after causing depreciation at these points larger particles of the metal such as broken balls or rolls may get between the gear teeth and seriously damage these members.

Q. Describe care of driving chains and sprockets.

A. To secure efficient operation of driving chains it is imperative that these be kept clean and in proper adjustment. If the chains are allowed to get dirty the grit that accumulates on the surfaces will wear out the sprockets very fast and some of the abrasive matter will also wear the driving chain rolls. It is good practice to remove chains at least every five hundred miles and clean these thoroughly by immersing in a bath of kerosene oil, allowing them to soak until all grit is washed out. They are then immersed in lubricant composed of mineral grease and graphite which has been heated so it is fluid enough to penetrate all the crevices of the chain. After the chain has been sufficiently lubricated it is taken out of the hot oil and is allowed to drain. The sprocket should be thoroughly cleaned and if the teeth are worn hook shape the sprocket may be reversed, if it is removable, so the hook side of the teeth will come in action only when the reverse gear is employed. In this way it is possible to obtain greater life from worn sprockets, though the best method of repair will be to replace the worn members.

The small sprockets on the drive shaft or at the end of the counter shaft will wear much sooner than the large sprockets on the driving wheels. If sprockets and chain are worn it is best to renew sprockets as well as the chain instead of trying to run a new chain on the old sprockets. Chain breakages are due principally to worn rivets or side plates which reduce the strength of some of the links, whereas rapid wear of the chains may be attributed to lack of proper lubrication and cleanliness. Drive chains should be adjusted so that there is some slack in the chain. If the radius rods are screwed up too tightly so the chain is under tension it will not only produce

considerable noise but is apt to snap. Chains are tightened by lengthening the radius rod extending from the jack shaft to the rear axle.

Q. What parts of shaft drive system are apt to cause trouble?

A. The parts of a shaft drive system that may cause noisy drive are worn universal joints and drive gears. The only condition that will cause failure to drive is either breaking or shearing of the propeller shaft (which seldom happens) the shearing of a key or driving pin in a universal joint hub and the failure of the fastening means that hold either the bevel drive pinion on the propeller shaft or the ring gear on the differential.

Q. How is wear in universal joints indicated, and how can it be remedied?

A. If universal joints are worn, this condition will be evidenced by a clicking or knocking sound when the clutch is engaged or the drive interrupted and when the brakes are applied. The wear is usually present in the universal joint cross or the pins on which this member oscillates. Most universal joints are provided with bronze bushings that may be driven out and replaced with new members when they wear. If the pins are worn, new case hardened members may be inserted. If a universal joint is properly lubricated, it is not apt to depreciate rapidly, so where these members are run in exposed locations it will be well to house them in a leather bag which can be filled with the lubricant. This serves as a protection against grit and also insures that the joint will be properly lubricated as the presence of grease between the working surfaces of the joints will cushion the shock present while driving and even if the parts wear to some extent the joint will not be noisy in action.

Q. What are main defects of driving gears?

A. Provided that the teeth are not worn unduly and that the bearings supporting the differential casing and bevel pinion drive shaft are not worn, noisy operation of the gears indicates either lack of lubricant or poor adjustment. If gears are not properly lubricated or are meshed too deeply, there will be a continuous grinding noise in the rear axle all the time the car is in operation. If the insertion of new mineral grease in the differential housing does

not silence the noisy action, the gears should be inspected to see that the teeth are not worn too much and that they are meshed properly. If there is too much play between the gears, there is apt to be a rattle or knocking in the rear axle instead of a grinding noise. If considerable looseness exists between the gear teeth, an effort should be made to eliminate practically all lost motion by moving the entire differential assembly nearer to the bevel pinion which can be easily done in most forms of floating axle or by meshing the pinion more deeply in the ring gear.

Q. Does differential gearing ever give trouble, and how is it evidenced?

A. The differential gearing of most cars is so strongly made and so simple in construction that it is not apt to cause trouble. Differentials of the bevel pinion type which have stronger teeth are not so apt to become broken as are those of the spur pinion type. If the differential is not functioning properly there will not only be difficulties in steering but there may actually be a failure in the final drive. The most common differential gear trouble is stripped pinion teeth. Sometimes, in cases where a differential has been used for some time, the gear teeth may become sufficiently worn so they will break off. The only remedy for this defective condition is to remove the entire differential assembly from the rear axle and substitute new gears. A differential is apt to be noisy in action if the pins on which the gears revolve become worn. If the driving keys or pins by which the live axle shafts attached to the wheels are driven become loose they are apt to shear off and failure of drive is inevitable.

LESSON THIRTY-FOUR

CHASSIS TROUBLES AND ELIMINATION

Q. What can be done if frame side member sags after it has been in service for a time?

A. The weakened frame member may be re-enforced by means of an internal steel plate that fits in the channel and which extends as far as possible on each side of the weak point or the frame may be brought back in place and kept in line by means of a simple turnbuckle truss rod which extends from one end of the frame member to the other.

Q. Why must frame members be straight?

A. If the frame members sag and the transmission and power plant are separate units, these members will get out of line and considerable binding of the clutch or gearset bearings may result.

Q. What happens if frame rivets are loose?

A. If the rivets by which the various gusset plates and cross members are secured to the frame side members become loose the frame structure is seriously weakened. If the rivets have become worn and the holes enlarged it will be necessary to replace them with larger rivets which must be forced tightly in the enlarged hole and then securely hot riveted in place. A frame having loose rivets is apt to squeak and will not maintain the proper alignment between the engine and the gearset.

Q. What attention do springs need?

A. Springs require very little attention, the main points being to keep the spring clips tight and to keep the spring shackle bolts oiled. The springs should not be allowed to get rusty because their smooth action will be impeded if rust accumulates between the laminæ or leaves of which the spring is composed.

Q. What is a sure indication of rusty springs, and how can it be prevented?

A. If springs are rusty, either at the spring shackles or between the leaves, a squeaking sound will be heard whenever the car is operated over roads requiring much spring action. This squeaking may be easily prevented by separating the leaves of the spring and inserting oil or graphite grease between them.

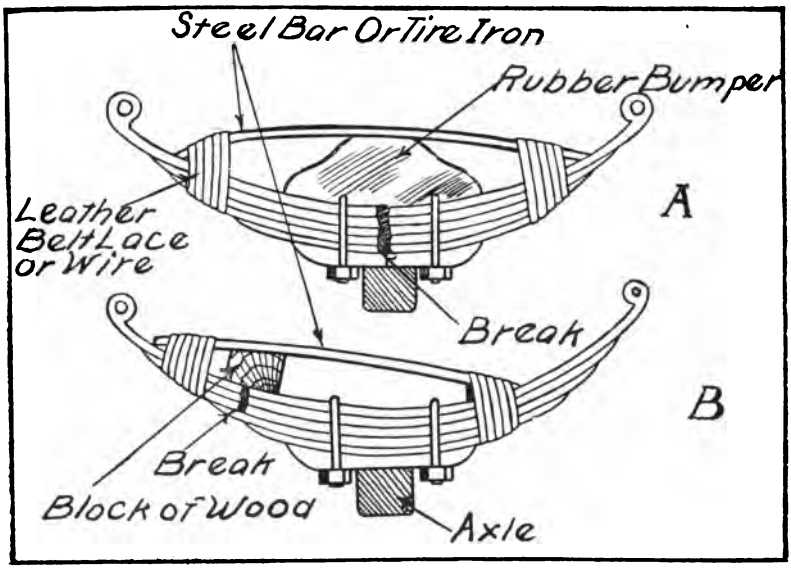


Fig. 296.—Methods of Making Emergency Spring Repairs Outlined.

Q. What causes spring breakage?

A. If a car is driven at high speed over very rough roads or if it is loaded beyond its capacity, the springs are apt to be deflected beyond the safe point and will break on the rebound, especially if the wheels strike an obstruction or drop into a hole in the road when revolving at high speeds.

Q. Describe emergency road repair in event of spring breaking.

A. If a spring breaks at the center where the bolt goes through as shown at *A*, Fig. 296, it may be repaired temporarily by placing

a rubber bumper or block of wood over the break and putting a steel bar or heavy tire iron over it and firmly attaching to each end of the spring by leather belt lace, rope, or wire. If the break is at a point between the center and one of the spring eyes, the spring may be repaired as outlined at *B*, Fig. 296. In this case the block of wood is placed over the fracture and the iron bar fastened to the spring, as indicated.

A useful accessory that may be carried in the tool box, as it occupies very little space, is outlined at Fig. 297. This spring repair member is a steel forging or casting, provided with a pair of repair clamps so it may be firmly secured to the spring member. This is

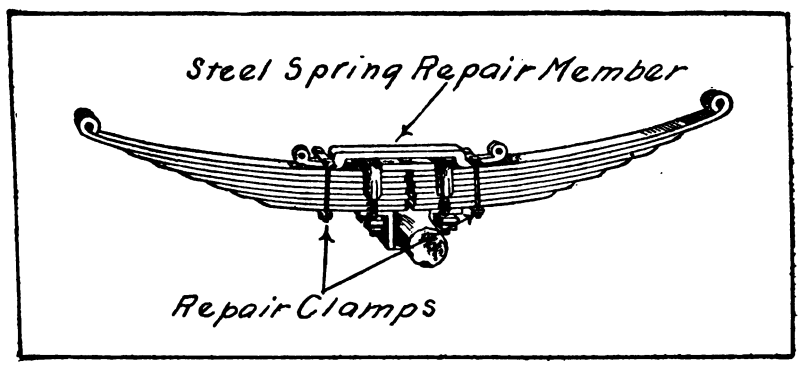


Fig. 297.—How the Emergency Spring Repair Member is Utilized When a Spring Breaks at the Center.

a much better temporary repair than those shown at Fig. 296 and the repair member is equally useful if the break is at the center or if it is near the end. One advantage of the construction is that it may be used to replace one of the spring eyes, should that member break off. If a spring breaks and no material is at hand for repairing it the spring may be relieved of the car weight by filling the space between the car frame and the axle with a heavy block of wood and tying this securely in place to prevent it from falling out. A car may be driven several hundred miles at moderate speed when repaired in this manner even if a spring is broken beyond repair.

Q. What is the main cause of back lash in steering gear?

A. The main cause of lost motion in the steering gear is depre-

ciation of the reduction gears and wear at the various joints on the drag link or tie-bar.

Q. How is lost motion in gears taken up?

A. A typical steering gear assembly and front axle parts are outlined at Fig. 298. Lost motion between the gears when of the form shown may be eliminated by removing the steering arm from the worm gear and turning that member around in its bearings so that new teeth come in contact with those of the worm on the steering pillar and then replacing the steering arm. The wear usually occurs at that point of bearing between the teeth in contact when the hand wheel is set in the straight ahead position because the irreversible worm gears used do not permit the steering post to turn when the wheels strike an obstruction and therefore all the shock is taken on the teeth of the gears.

If the bearings supporting the worm gear to which the steering arm is attached are worn, they may be replaced with new members so there is no lost motion at the bearing. If the steering post has an up and down movement, this may be prevented by screwing down the adjusting nut at the top of the gear casing, which will bring the thrust bearing parts in closer relation. If the ball thrust bearings are worn unduly, these members should be replaced. The hand wheel should be firm on the steering post as sometimes the key by which it is fastened may wear to such an extent that the wheel spider will be loose on the steering column even if the reduction gears are tight. Another point that demands inspection is the anchorage of the wheel rim on the spokes. Lost motion at the other points in the steering system will also tend to produce back lash at the handwheel.

Q. What causes stiff action of steering gear?

A. If the joints on the tie-bar and drag link become dry and the bearings of the worm wheel shaft and steering post are not properly lubricated the action of the gearing is apt to be stiff. Some forms of steering gears may be adjusted by eccentric bushings which may be oscillated to bring the worm and worm gear in closer relation. If the bearings are turned so that all lost motion is eliminated with the gearing in the straight ahead position, the action

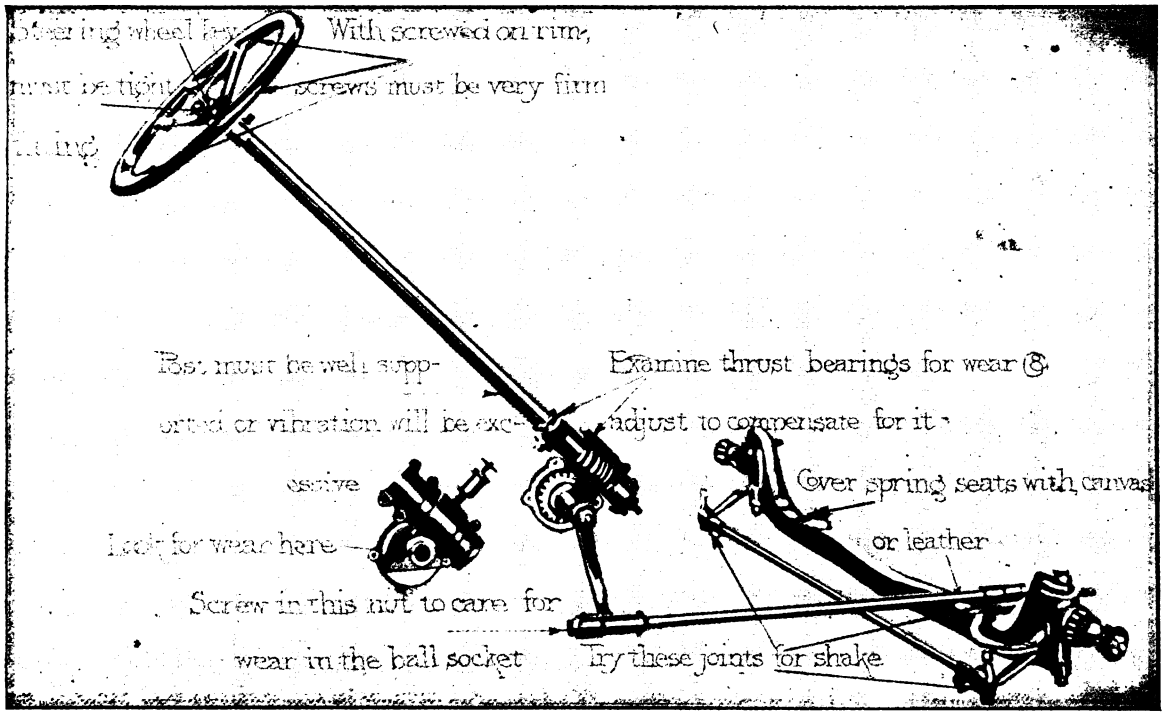

With screwed on rim,
screws must be very firm
Post must be well supp-
orted or vibration will be exc-
essive
Look for wear here
Screw in this nut to care for
wear in the ball socket
Examine thrust bearings for wear &
adjust to compensate for it
Cover spring seats with canvas
or leather
Try these joints for shake

Fig. 298.—Complete Steering System Including Steering Gearing and Front Axle Parts Showing all Points Where Depreciation Affects Positive Control.

is apt to be stiff when the hand wheel is turned because the teeth that have not worn because they are not used as much are brought in action when the worm is rotated to either extreme. Sometimes stiff action of the steering gear is due to accumulations of rust between the steel steering post and its surrounding tube. The steering knuckle spindle bolts also are apt to become dry and will assist in producing stiff action when in this condition.

Q. What can be done to eliminate lost motion in other parts of the steering system?

A. The point where wear is more apt to materialize is at the relatively small bearings on the tie-bar. The pins passing through the steering spindle may become worn or the bushings in the spindle arm bosses may wear oval. This lost motion may be easily eliminated by forcing new bronze bushings in place and renewing the worn pins. Owing to the large amount of bearing surface provided, the steering knuckle bolts are not apt to wear unless lubrication has been neglected. These and the bushings in the steering knuckles are also easily replaced. The joints at the end of the steering arm on axle and steering gear are apt to become loose, but as a rule these are adjustable ball and socket joints and can be easily tightened by a simple adjusting nut that brings the parts into closer engagement. Wear at these components may be easily detected by grasping the tie-bar or drag link firmly and seeing if they will move either endwise or up and down without moving the wheels. Wear in the steering knuckle bolt may be detected by jacking up the front axle and grasping the wheel rim at top and bottom to see if there is any play at the steering knuckle. There are two points in the steering system that must be inspected frequently. These are the joints on the drag link and those on the end of the tie-bar.

Q. How can depreciation at the tie bar and drag link yokes be prevented?

A These parts should be lubricated and kept clean. A good precaution to take is to enclose these in leather bags which may be securely fastened around them and which may be packed with grease so the joints are not only continuously lubricated but are also kept free of dirt.

Q. What points on the front axle are liable to give trouble?

A. Practically the only parts that need inspection on the front axle are the wheel bearings which must be kept in proper adjustment. Full instructions are given for the care of all types of anti-friction bearings in a preceding lesson.

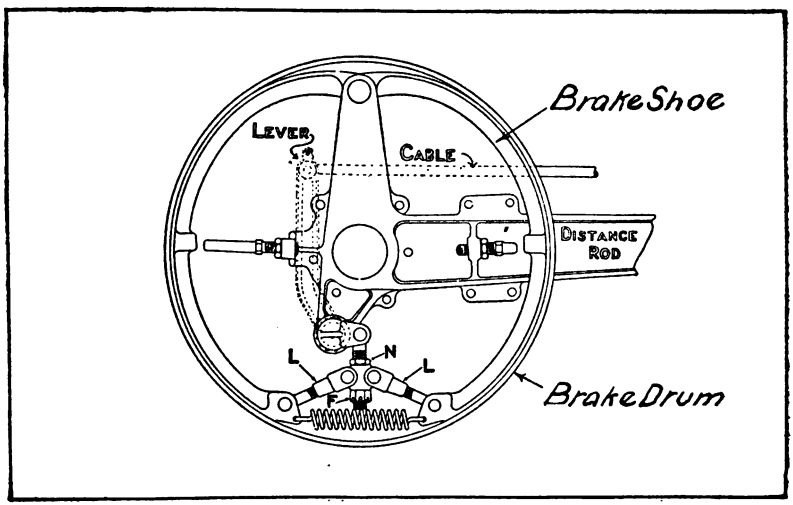


Fig. 299.—Toggle Actuated Internal Expanding Shoe Brake, Showing Adjustments to Compensate for Brake Shoe Wear.

Q. What is the main cause of stiff control lever or pedal action?

A. Accumulations of rust at the bearing points of the clutch pedal or hand lever supporting shafts will make these members work hard. The rods may spring or become bent and this also will produce friction to prevent easy operation. These members may be freed up by soaking the affected parts liberally with kerosene to cut the rust and then oil the bearing points. If a lever supporting rod or tube is sprung or bent it must be straightened.

Q. What causes brakes to slip?

A. Internal brakes such as illustrated at Figs. 299 and 300 may slip if there is too much oil between the braking surfaces or if the shoes are worn so they do not bind against the brake drum in the

proper manner. Sometimes the brake shoes may be faced with some friction material and when this wears the brakes will not engage properly. Often the friction material may wear down so the rivet heads by which it is held are flush with the surface of the material. Under these conditions, the rivet heads bear on the brake drums instead of the friction material and owing to the very limited surface the retarding action is not sufficient and the brake will slip even though maximum pressure is applied at the brake pedal or hand lever.

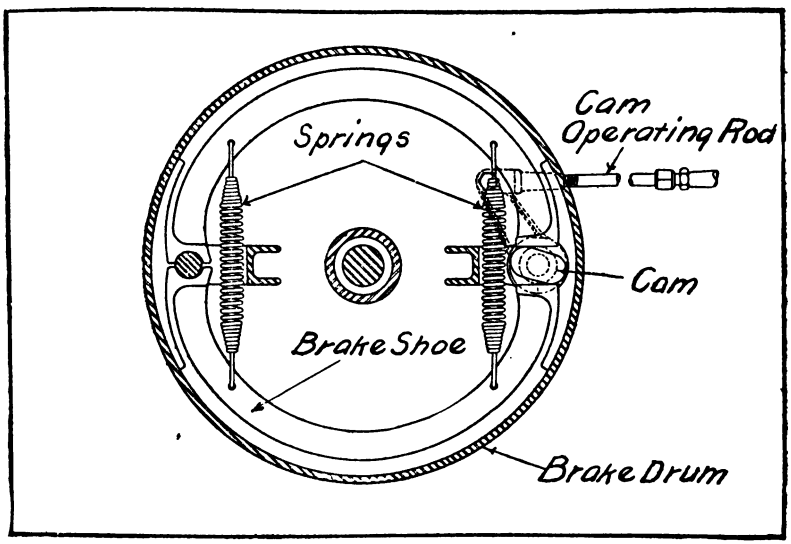


Fig. 300.—Cam Actuated Internal Brake.

Q. What means are provided for compensating for external brake band wear?

A. On practically all brakes of the external form the band is provided with some method of compensating for depreciation. The usual means is a turnbuckle or screw arrangement that permits one to take out lost motion by tightening the band a little more around the brake drum. If the brake rattles and does not apply promptly it may be considered an indication that it needs adjust-

ment. If the material is worn down so the steel bands are exposed in several places, the friction material must be renewed before attempt is made to adjust the brake.

Q. What means are provided for allowing for wear of internal brakes?

A. An internal expanding brake of the type shown at Fig. 299 may be adjusted for wear by loosening the lock nut *M* and the adjusting nut *F* and screwing *F* down so the shoes may be expanded to some extent when the lost motion existing between *F* and the toggle actuator which slides on the threaded rod fastened to the brake operating bell crank is prevented. When the proper amount of adjustment is secured the lock nut *M* is screwed down tightly against the toggle actuator; bringing the toggle actuator nearer the brake drums compensates for wear of the shoes. If the shoes are worn to such an extent that adjustments cannot be made by moving the toggle actuator, the pins in the yoke members *L* may be removed and the yokes screwed out several threads after which the pins are again replaced. In the form of brake outlined at Fig. 300, where a cam is used to spread the brake shoes instead of a toggle leverage, the only way that wear between the surfaces may be corrected is by shortening the cam actuating rod. This may have a turnbuckle or may be provided with a thread that screws into the hub of the yoke member by which the rod is attached to the lever that rocks the cam. Brakes of the type shown sometimes employ shoes faced with Raybestos or similar material and if this wears down so the full travel of the cam does not apply the brake properly it is necessary to reface the brake shoes. Cast iron or bronze shoes must be replaced with new members when worn to a point where adjustment of operating lever or cam is futile.

Q. What happens if brakes are adjusted too tightly?

A. If the band of an external brake or the shoes of an internal expanding type are adjusted so that they bear against the brake drum at times when there is no pressure at the foot pedal or hand lever they will bind and resist rotation of the drums and materially reduce the speed and power of the car because of the friction between the brake drums and retarding members.

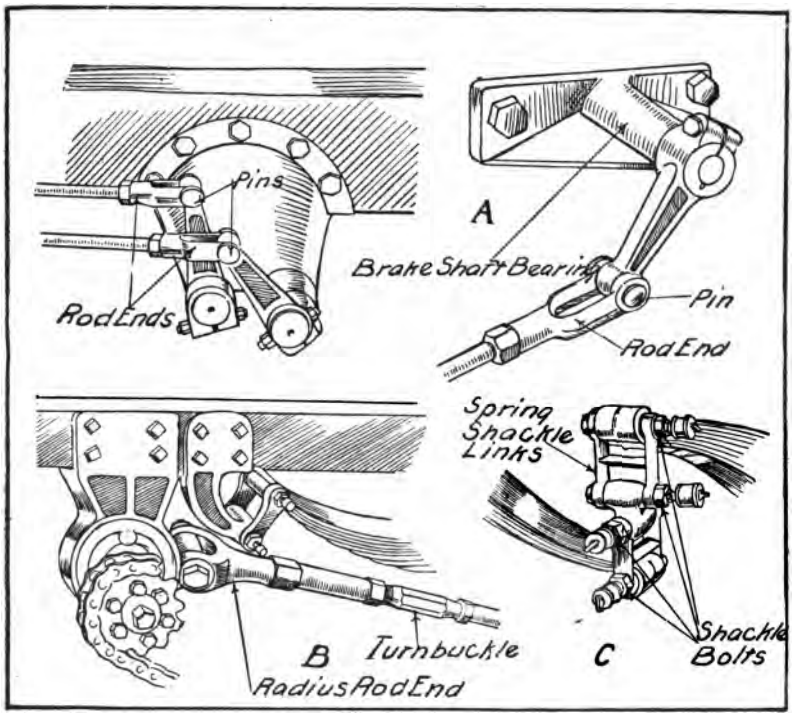


Fig. 301.—Miscellaneous Points on the Motor Car Chassis Where Depreciation Will Produce Noisy Operation.

Q. What is positive indication of binding brakes?

A. One can tell if the brakes are binding by releasing the clutch and attempting to coast down a hill without using any of the engine power. If the brakes are free the car will coast without difficulty and make good speed. If the brakes are binding to some extent they will hold the car back and reduce the speed. After a run where the brakes have not been applied frequently the brake drums may be examined for heat. If considerable friction has been present between the brake members, the drums will be so hot that they cannot be touched with the hand. If the binding is not remedied, the friction is apt to become great enough so the brake linings or facings will be burnt or charred and will need replacement.

Q. What effect does wear in radius rod or torque rod anchorage have?

A A typical radius rod is shown at *B*, Fig. 301. If wear exists at the yoke at the front end where it is attached to the jack shaft or at the rear end where it is fastened to the axle, there will be considerable rattle and knocking while the vehicle is in operation. These sounds will be more in evidence on rough roads than on smooth highways because axle movement is greater. The wear commonly occurs on the bear ng pins in the radius rod end. If the portion is wh ch the pin seats is bushed the bushing may be replaced, though if the boss is of solid metal it must be drilled out, forming a large size hole, and a larger p n fitted. Most radius rods used for chain adjustment are provided w th some form of turnbuckle so the rod may be lengthened or shortened to increase or reduce chain tension.

A number of points in the brake actuating mechanism where depreciation will cause rattle are shown at *A*, Fig. 301. If the brake shaft bearings wear, they must also be carefully refitted if any great amount of wear exists at those points. Another point to be looked after carefully are the spring shackle links and spring shackle bolts as depicted at *C*, Fig. 301. If these members get dry, there will be considerable squeaking, whereas if too much lost motion exists, the bolts are apt to wear through quickly or crystallize and break because of the continual hammering action and vibration they are subjected to when loose. Many mysterious rattles and squeaks while a car is in operation have been eliminated by proper attention to the various minor components comprising the brake rod, radius or torque member anchorage and spring shackle assemblies.

LESSON THIRTY-FIVE

FIXING TIRE DEFECTS

Q. Describe complete outfit for care and repair of tires.

A. The supplies and tools necessary for tire repair depend entirely upon the character of the tires the vehicle is fitted with and whether the motorist desires to make temporary or permanent repairs on the road. An important accessory that is usually included in the outfit of all cars using pneumatic tires is shown at *A*, Fig. 302. This a double acting tire pump of large size and is intended to be operated by hand. For temporary repairs, the complete tire outfit depicted at *B* will take care of almost anything that may happen from a simple puncture to a blowout. It contains patches, tire tape, tire removing and applying irons, blowout sleeve and inner liner, emery cloth, fabric, and cement. The jack illustrated at *C* is a powerful form adapted for all types of cars and is operated by the detachable handle *B*, which may also be used as a lever or pry when making tire repairs. In order to make a sure repair when patching an inner tube, many motorists carry a "cold vulcanizing" outfit in which the cement is cured by acid and which will make a much more secure patch than the plain rubber cement will. On some heavy cars, capable of considerable speed, it is almost impossible to make the average cement patch hold, and a vulcanizing set, as shown at *E*, Fig. 302, is a necessity.

At Fig. 303 a number of tools that may be included in the outfit to advantage, provided that the equipment does not already include a repair kit of the type shown at *B*, Fig. 302, are outlined. The pressure gauge is a useful indicator of the amount of pressure contained in the tires and as most makers recommend a definite amount of inflation for various sizes of tires it is well to have a

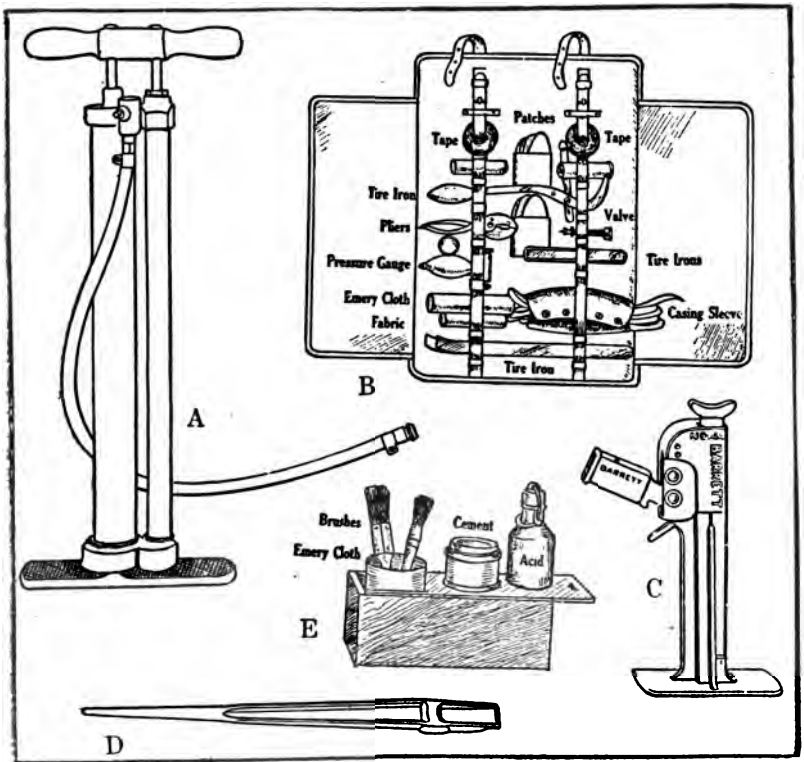


Fig. 302.—Complete Tire Repair Outfit, Enabling the Motorist to Cope with Any Form of Tire Trouble.

gauge to make sure that they are blown up to the proper point. If a casing remains on the rim for some time without having been removed, it is apt to rust or become so tightly wedged in place that it cannot be removed by the ordinary forms of tire irons. The casing release iron illustrated is adapted to force the bead of a heavy clincher tire out of the rim flanges without requiring the expenditure of much power. The four tire irons are supplied to remove and apply clincher casings and are useful adjuncts to the casing release iron. The 4 in 1 valve tool is very handy when it is needed as sometimes the valve may be damaged when removing or inserting an inner tube, especially if the valve stem is carelessly struck with the

tire iron to remove it. If the threads are damaged on the outside of the valve stem so the valve cap will not go on, the threads may be recut by using a small die in the center of the tool. If the thread is damaged on the inside of the valve stem it may be cleared out by using the tap projecting from one end of the die and serving as a handle by which it may be turned. The other projecting arm is a key to unscrew the valve inside, while the short projection is a face reamer or cutter for removing any burr that will prevent the valve cap from seating securely on the stem. The thermometer shown is the standard form used with all types of small portable vulcanizers. It is not necessary, unless a vulcanizer is carried as part of the equipment.

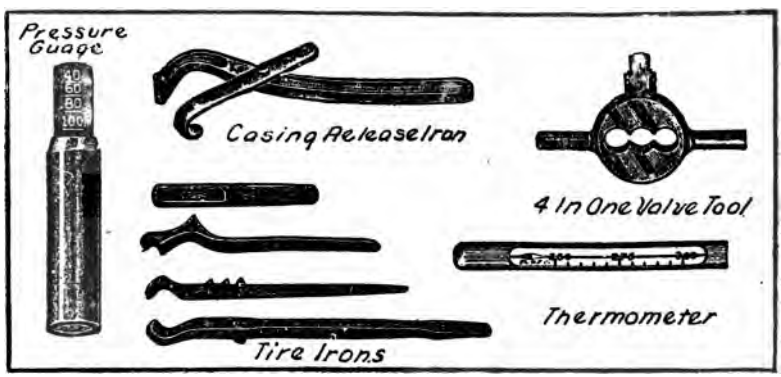


Fig. 303.—Useful Accessories that Facilitate Maintenance and Repair of Tires.

Other parts that may be carried to advantage are shown at Fig. 304. Many motorists find that attempting to patch an inner tube on the road consumes too much time so spare tubes are carried in a suitable case and are inserted in place of the damaged member without any more delay than is necessary for replacing one tube with another. The injured tubes may be repaired at leisure, and carried as a spare when restored to the proper condition. The valve inside, valve cap, and valve cap washer of the standard shrader valve are also shown. It is well to always have at least a half dozen of the valve insides and three or four of the caps and

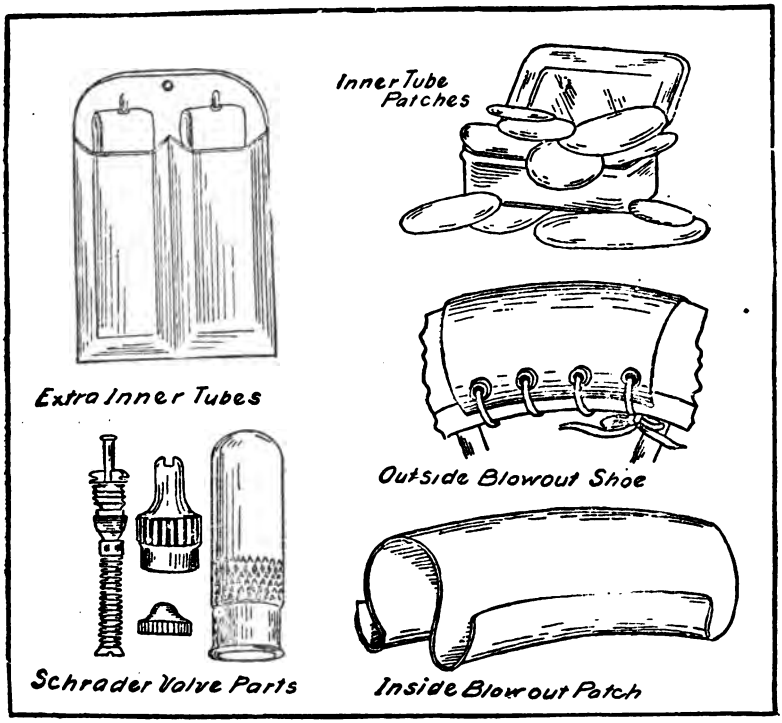


Fig. 304.—Some Extra Parts That May be Carried to Advantage for Repairing Tires.

rubber washers in the repair kit. One or two of the valve stem covers which protect the valve stem assembly may also be carried as these are sometimes jarred off by vibration. A box of cementless inner tube patches are also useful in event of trouble with the cement or vulcanizing solutions. These are coated with a special cement, which is made ready for action by covering the treated side with gasoline before it is attached to the tire. The outside blowout shoe and the inside blowout patch shown are also useful in cases of serious damage to the outer casing.

Q. What kind of tires are most liable to give trouble?

A. Pneumatic or air filled tires are more apt to give trouble

than solid or cushion tires but at the other hand it is practically impossible to repair either solid or cushion tires on the road because these can only be restored to efficiency by experts familiar with the construction and compounds used in making them. While the pneumatic tire is apt to give some trouble repairs may be made by any one of average intelligence, and if a reasonably complete repair outfit is carried, the ordinary run of tire defects is not apt to cause any serious delay or inconvenience.

Q. Name principal troubles with pneumatic tires.

A. Pneumatic tire troubles may be produced from two causes; wear or weakening of the outer casing and various inner tube defects which will permit the air to escape. While the tire is in use it is subjected to considerable wear on account of the abrading action of the road surface and the casing tread may depreciate without affecting the inner tube, though any object that penetrates the casing is apt to go through the air tube as well. The most serious trouble is puncture or blowout which permits the air to escape, and which makes changing the defective tube imperative before the journey can be continued.

Q. What are the troubles incidental to solid rubber or cushion tires?

A. Solid rubber or cushion tires may be punctured or cut without causing any immediate trouble though all incisions and abrasions weaken the structure. A tire of either of these forms may be cut enough so that it is apt to come off at the rim, but as a rule the greatest trouble is depreciation due to natural wear.

Q. What are causes of punctures?

A. Any sharp objects in the roadway, such as nails, broken glass, sharp stones, or any matter of that nature, are apt to go through the casing and inner tube as the wheel rolls over them. This makes a hole and relieves the air pressure so the tire becomes deflated in which condition it is not suitable for use. Punctures are more apt to occur in cities than on country roads, and are more apt to result after tires have been used for a time and the rubber softens and fabric weakens than when tires are new. If a vehicle is used

continuously on oiled roads this substance will produce depreciation and softening of the rubber composing the tread. If tires are run soft, they are more liable to be punctured than are properly inflated casings.

Q. What is the difference between a puncture and a "blowout"?

A. A puncture usually comes from outside whereas a blowout is often due to defects in the tire itself.

Q. What are causes of "blowout"?

A. A blowout generally results when the fabric at some point in the casing becomes too weak to resist the air pressure contained in the inner tube. If a cut is neglected in an outer casing, water is apt to work in between the plies of fabric comprising the carcass of the shoes and as this rots the textile material which is depended on to give the casing its strength, the inner tube will blow through when the fabric can no longer resist the air pressure. Sometimes a sharp stone may cut through the casing tread and two or three layers of the fabric, and it is not long before the rest of the fabric deteriorates at the weak portion. Blowouts may occur in the tread, in the side wall or at the rim channels, whereas punctures generally occur on the tire tread.

Q. What is the best method of repairing punctures?

A. The best method of making a permanent repair of a punctured inner tube is to use a vulcanized patch, though temporary repairs may be made by using rubber cement. Vulcanizing may be done by either hot or cold process.

Q. What is hot vulcanizing process?

A. The hot vulcanizing process consists of repairing the cut with raw rubber which is vulcanized or joined to the tube by the application of heat. Vulcanizers are simple devices that may derive their heat from a naked gasoline or alcohol flame or by resistance coils through which an electric current is passed. A hot vulcanizer is shown in operation at Fig. 305. It consists of a cast iron or aluminum body portion filled with water and having a central aperture in which the flame of the lamp suspended beneath the

device may be used to change the water to steam. Other forms consist merely of a casting heated directly by the flame instead of by the hot water or steam. The body portion of the vulcanizer is provided with lugs by which it may be fastened to the casing or held against the tube as shown.

Sometimes the vulcanizer is a combination form having curved and flat faces as shown at *A*, Fig. 306. In this case, the device is adapted to work on outer casings and inner tubes simultaneously. A simple form of vulcanizer suited for repairing inner tubes is shown at *B*, Fig. 306. These are inexpensive and easily used. The de-

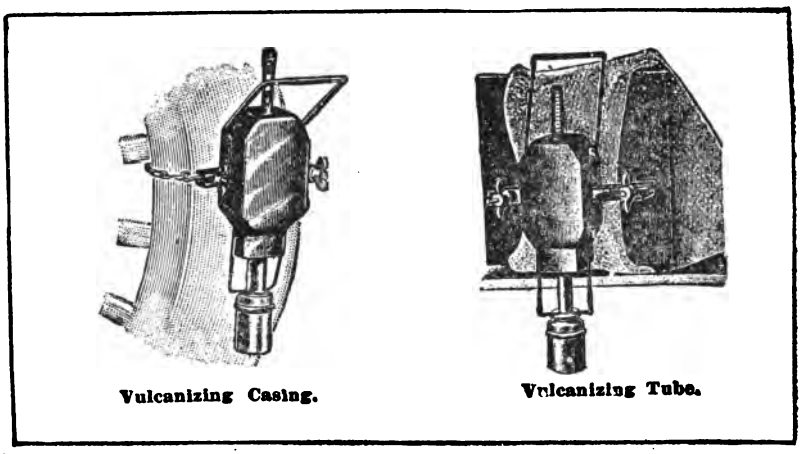


Fig. 305.—How Flame Heated Vulcanizers May be Used in Repairing Outer Casings or Inner Tubes.

vice consists of two iron castings adapted to clamp the tube between them, one of the castings carrying studs and thumb screws so the other member may be clamped tightly against the inner tube. To vulcanize a patch, the tube is clamped in place between the two castings, the pronged member uppermost. A piece of specially prepared rubber adapted to be vulcanized is placed over the puncture. A measured quantity of gasoline is poured in the receptacle forming part of the upper casting and is ignited. The flame of the burning gasoline surrounds the conical projections which conduct the heat to the bottom of the plate and against the patch. The plate is

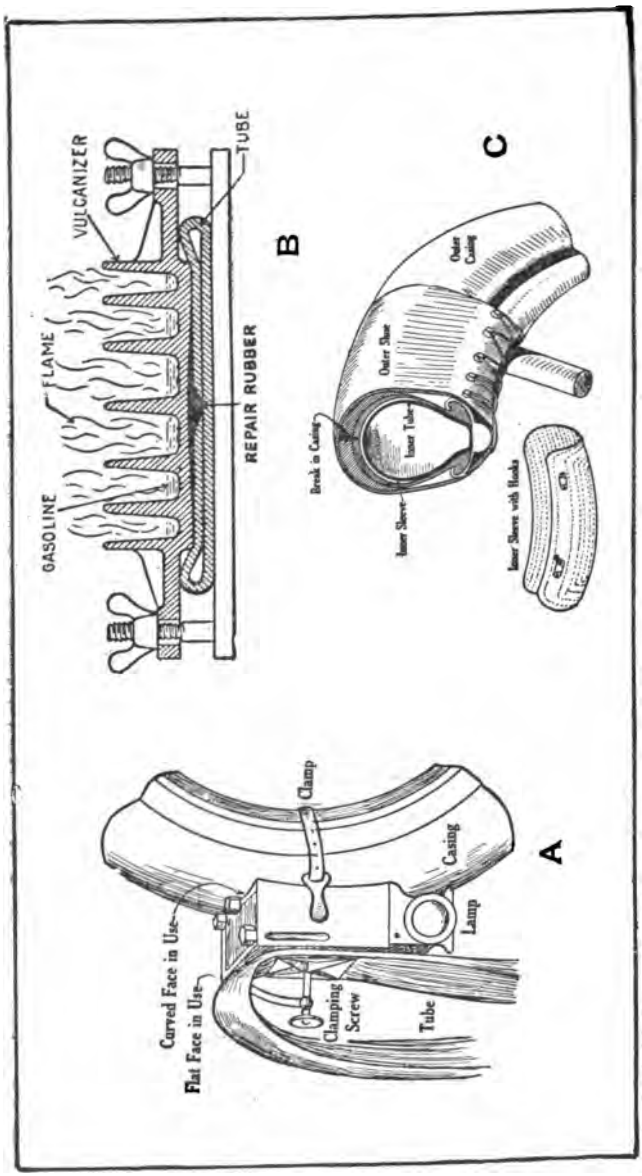


Fig. 306.—Showing the Application of Various Accessories in Repairing Cuts in Casings, Patching Inner Tubes and Making Temporary Repairs of a Blowout.

prevented from becoming too hot by using a previously determined quantity of gasoline in the cup which generates just enough heat to complete vulcanization without any possibility of burning the tube. These simple vulcanizers are generally sold complete with a measure to show the amount of gasoline necessary, small scissors, emery cloth, cement and specially prepared rubber for patches.

Q. What is "cold vulcanizing" process?

A. The "cold vulcanizing" process requires the use of a special cement and curing acid though it may be used with the regular cured patches furnished for cementing. The cement is applied to the patch and tube and is then covered over with the acid after which the patch is pressed firmly in place immediately and held there by some clamping means or a weight until the process is complete.

Q. Describe method of repairing a puncture with a cemented patch.

A. The first thing to do is to locate the hole through which the air is escaping. If it has been caused by a nail or other large object it may be easily found by examining the tube, but in some cases it may be a very small puncture that cannot be discovered readily. After removing the inner tube blow it up until it is distended to its normal size. Do not put enough air in the tube to stretch it as if the pressure is too high it may enlarge the hole. If a bucket or trough of water is at hand immerse the tube in the water a little at a time, at the same time slightly stretching the tube. If this is done carefully air bubbles will be seen rising from the leak no matter how minute it is when the injured portion of the tube is under water. If it is impossible to get enough water to immerse the tube, dampen the hand and pass it along the tube surface. The wet hand is very sensitive to even the slightest air current and the leak can be found very readily in this manner. Another way to locate a leak is to blow the tube up and then pass it close to the ear, revolving it slowly so that all parts of the tube are passed before it. The leak will be evidenced by a hissing noise which is in proportion to the size of the leak. A good way of marking the leak positively is by means of an indelible pencil which will leave a mark on the rubber when moistened that will not come off.

A piece of sand paper or emery cloth is usually provided in a repair kit and with this all of the gray deposit from the rubber should be cleared from an area around the puncture somewhat larger than the patch to be fitted. This talc and powdered rubber may also be washed off with gasoline or scraped off with the blade of a jackknife if the sand paper is not available. It will be well to treat the surface of the patch in the same manner and to roughen up the clean surfaces of both tube and patch with sand paper or a wire scratch brush. A light coat of cement is then applied to both patch and inner tube and is allowed to dry for five or six minutes. Then the operation is repeated and more cement is spread over the surface. This is also allowed to dry, and when the surface is sticky the patch is pressed firmly in place and held in position by a clamp or some other means that will produce pressure. The patch should be allowed to set for ten or fifteen minutes before replacing the tube. Powder the patch and tube freely with soap stone or talc to prevent the tube sticking to the casing.

It is well to examine the casing before replacing the tube to be sure that the cause of the puncture is removed. This may be done by examining the exterior of the casing and by passing the hand around on the inside. The puncturing object often becomes imbedded in the rubber and while it is not visible from the outside it may stick through the casing and protrude on the under side. Temporary repairs to the casing should be made from the inside. A piece of fabric three or four times the width of the hole and long enough to reach from edge to edge of the casing should be cemented in place. This is done by cleaning the lining of the casing and applying two coats of cement, while the prepared fabric which is already coated with rubber should be wet with a little gasoline before it is pressed in place in the inside of the shoe.

Q. What is the best temporary method of repairing "blowouts" in casings?

A. A good temporary repair of a burst casing can be made by using an inside and outside blowout patch as shown at *C*, Fig. 306. A new inner tube should never be inserted in a burst casing without first taking some precautions to close the hole or rent both from

inside and outside or the tube will blow through at the weakened spot of the shoe before it has been in use for any length of time. The inner patch is composed of several layers of frictioned fabric (fabric impregnated with rubber compound) and the larger sizes are provided with hooks which engage the rim if a clincher type is used. It is from six to eight inches long for small tires and ten to twelve inches long for the larger sizes. The strength of fabric used also varies with the size of the tire the patch is made for. This is placed in the casing in such a way that the rent comes at a point approximately at the center before the inner tube is inserted. After the casing is replaced and inner tube partially inflated, the outer shoe or patch, usually of leather or fabric and rubber compound is laced tightly in place around tire and wheel rim and then inflation of the tire is completed. A repair made in this manner is reliable enough so the tire remains in service for some time without attention though the temporary patches should be replaced by a permanent repair at the earliest opportunity.

Q. How are "blowouts" repaired permanently?

A. To repair a badly cut or rent outer casing it is usually necessary to rebuild the casing at the injured part. The injured fabric is cut out and replaced with new, and new tread rubber is also applied to the outside of the casing. The layers of fabric and rubber are well cemented with special material adapted for curing and are thoroughly vulcanized together and amalgamated with the remainder of the shoe. In cutting out the old fabric, the first inside layer is cut out at least six inches each side of the blowout. The next layer is stripped off for five inches each side of rent, then two or three of the succeeding layers are taken off for the same distance say four inches each side of the injury. In replacing the layers with new fabric, it is cut to fit the steps left when the injured material has been removed. Building up in this manner makes a much stronger repair than just replacing the injured material would because each layer applied reinforces the others beneath it and when the last ply is in place and all firmly joined together by the curing process the shoe is practically as good as a new one.

Q. What causes rim cutting?

A. Rim cutting is usually caused by running the tire flat or not inflated sufficiently. It is sometimes due to rusty or rough rim edges or to poorly fitting rims or improperly designed beads on the tire casing.

Q. What causes stone bruises, and to what are sand blisters attributed?

A. If a tire, even when well inflated, strikes a sharp stone at high speed this is apt to tear off a portion of the tread and often injures several plies of the fabric. This is called a stone bruise and weakens the shoe to some extent, depending upon the amount of material removed from the casing or the depth of penetration and its location. The shoe is weakened much more if the tread is damaged than if the side wall is scraped. If a stone bruise or other cut penetrating the tread is neglected, sand or road gravel is apt to work into the tire as it revolves and this material soon accumulates between the tread and fabric or between the layers of fabric until it forms a protuberance of some size. This is called a sand blister. The action of this compacted material is to break down the layers of fabric between it and the tube and the casing inevitably blows out if the defective condition is not remedied.

Q. What can be done when treads wear?

A. If the tread portion of the casing wears from abrasion with the road and the fabric carcass is in good condition and free from weak spots it will be found economical to retread the casing. This is done by stripping off all the old tread and several of the worn layers of fabric, rebuilding the tire with new material and curing the whole by vulcanizing in a mold or by a wrapped tread process around an iron core.

Q. How can weakened casings be strengthened to obtain more service?

A. Weakened casings can be used for some time by the insertion of a reliner of fabric which strengthens it and presents a solid, unbroken surface for the inner tube to bear against. An outer casing or leather protector may also be employed.

Q. Why should cuts in casings receive immediate attention, and how can they be filled up?

A. Cuts in casings allow water to enter and rot the fabric even if they are not sufficiently large to weaken the shoe appreciably. They may be easily filled up by using the special repair pliers shown at Fig. 307 to spread out the rubber and open the cut sufficiently to clean it out with gasoline and insert special cement and repair gum. When the pliers are withdrawn, the rubber closes around the repair material and when the gum hardens it fills the hole thoroughly.

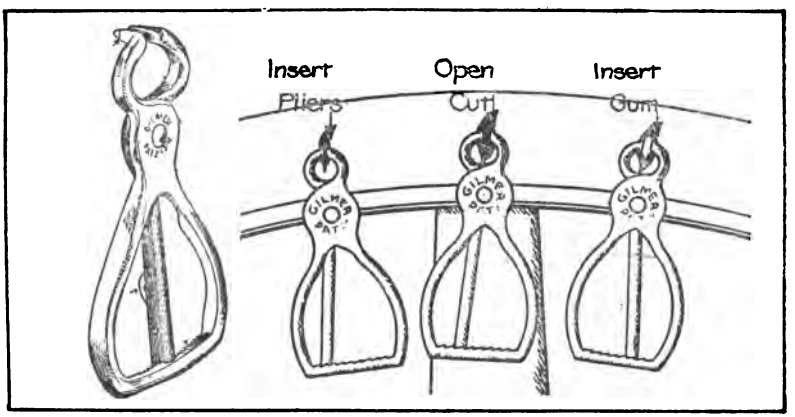


Fig. 307.—How Special Repair Pliers May be Used in Opening Incisions in Tire Tread to Insert Repair Gum.

Q. What precaution should be taken in removing or replacing inner tube?

A. When removing or replacing inner tubes from casings, especially those of the clincher type, it is necessary to use the tire irons or levers employed to pry out the casing bead from the rim channel very carefully or the tube is apt to be pinched and perhaps badly cut. The correct use of the iron in detaching the casing is clearly shown at Fig. 308 *A* and *B* while the manner in which the tire iron or the casing bead may pinch the tube and cause rupture is depicted at Fig. 308 *C* and *D*. In replacing a tube, it is always well to inflate it enough to round it out before the last bead is inserted. In removing a casing from a rim always start at a point opposite the

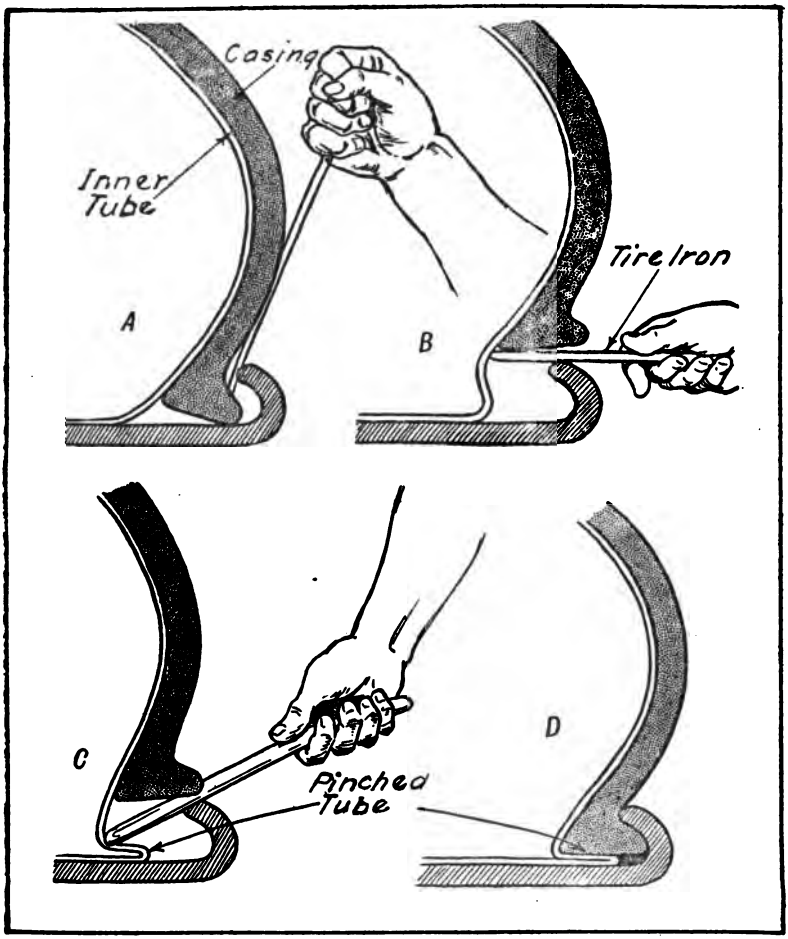


Fig. 308.—Proper Methods of Handling Tire Irons in Removing and Replacing Outer Casings at A and B. How Inner Tube May be Pinched if Carelessly Fitted at C and D.

inflation valve while the valve stem is always the first thing to insert in the wheel when replacing a tube and those portions of the casing adjacent the valve should always be replaced first.

Q. How can rusted on casings be removed?

A. Casings or locking rings that have become rusted to the rim may be easily loosened by using the special tools made for the purpose outlined at *A* and *B*, Fig. 309. The former is employed to loosen a sticking lock ring, the latter enables the motorist to exert great pressure against a wedged bead without expenditure of much effort. The tool shown at *A*, Fig. 310, is similar in action except that the power is multiplied by a toggle leverage rather than a rack and pinion gear. The devices shown at Fig. 309 *C* and *D* are to assist in replacing stiff clincher casings as they serve to hold the shoe in place on the rim while the operator is prying on other parts with the levers.

Q. What happens if pneumatic tire is run flat?

A. The tire will be destroyed if run for any length of time without air because the casing will be rim-cut and otherwise bruised, the layers of fabrics are apt to become separated and the tube will be so badly cut that it cannot be repaired.

Q. What indicates a flat tire in front? In the rear?

A. When one of the front tires is flat, in addition to the bumping always present when a tire is deflated there will be some difficulty in steering. If a rear tire is too soft, there will be more bumping than with a flat front tire and the car will lose speed.

Q. What can be done to save the shoe if tire is flat and it is not possible to repair it?

A. If one can get some old rope, the tire may be removed from the rim and the rope wound around until it has sufficient thickness to keep the rim from contact with the road. If no rope is available, the casing may be filled with hay, straw, old cloths or bagging or similar material which will afford partial support and often enable one to cover several miles at low speed before the filling will need renewal. When a casing is filled, it should be well tied or strapped on the rim at several points because the filling will not hold it in place as will an air filled inner tube.

Q. What troubles may occur in valve, and how may leakage be easily detected?

A. The chief valve trouble is leakage due to a particle of dirt

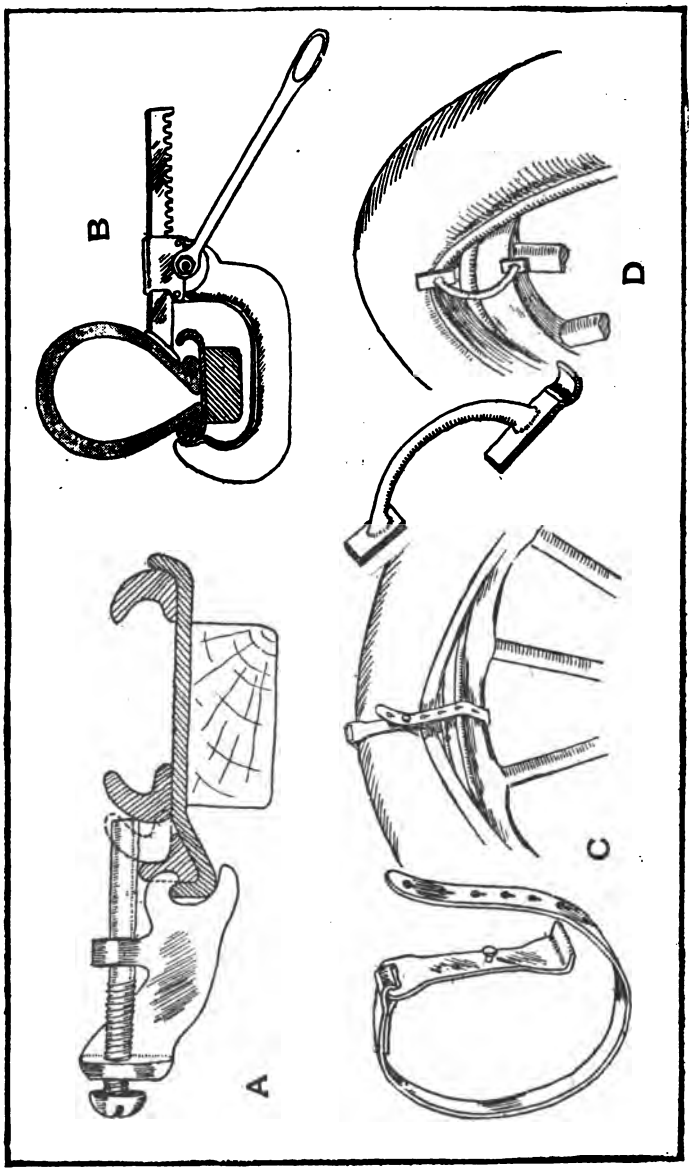


Fig. 309.—Useful Accessories and Tools to Assist in Removing or Applying Stiff Outer Casings.

under valve seat or depreciation of the small rubber member designed to close the valve stem bore. Sometimes the valve insides are not screwed in tightly enough or the small spring or inner stem may become rusted together and thus keep the valve from seating as it should. A leaky valve may be easily detected by placing it at the top of the wheel so it points down and allowing the end to stick below the surface of a glass of water. Any leak will be shown by air bubbles. The cheapest method of repairing a leaky valve is to replace the entire inside mechanism which costs but a few cents.

Q. Describe method of removing and replacing inner tube in outer casing of the clincher type.

A. The first step is to take off the valve stem lock washer and nut that holds it against the wheel felloe and then loosen any tire lugs or security bolts that may be used. The valve inside is then removed so any air contained in the tube may escape. The outer bead of the casing is then pried out of the channel in the rim with the tire levers, beginning at a point opposite the valve. Either the strap or the simple lever shown at Fig. 309 will be found as useful in keeping the tire bead out of the rim as they are in keeping it in when applying the shoe. After the shoe has been freed from the rim at one side the inner tube may be pulled out and if this is the only member that needs attention it is not necessary to remove the remainder of the casing from the wheel. If it is necessary to repair or replace the casing, it may be taken from the rim by inserting the tire irons from the inside of the wheel and prying the inner bead over the outer rim channel until about half of the casing is free from the rim. It will be found easy to pull the remainder of the shoe from the wheel without any tools. The shoe of a quick detachable rim comes off very easily after the locking ring is removed as when deflated it may be slipped off the rim complete with inner tube and may be replaced in the same manner.

Q. What are tire protectors, and how are they made?

A. Tire protectors are of two forms, those intended for application to the interior of the casing and other forms constructed for application to the outside of the shoe. The form at *C*, Fig. 310, is an inner liner composed of a number of layers of fabric vulcan-

ized or cemented together as in tire construction and is intended to reinforce a weak shoe, such as one having a number of stone bruises or other weakness of the carcass but still possessing a serviceable tread.

The protector depicted at *D*, Fig. 310, is usually made of chrome tanned leather and is designed to completely cover the shoe. These leather treads are provided with hooks for attaching to the rim channel or with straps for securing to the wheel by strapping under the felloe. They are also studded with steel rivets designed to take all of the wear from the leather on rough or stony roads and also

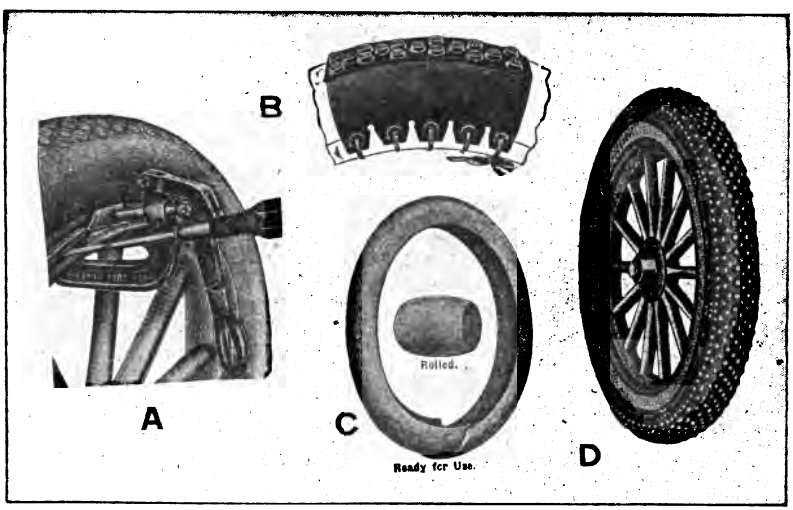


Fig. 310.—Outlining the Two Main Forms of Tire Protectors.

to provide some degree of protection from skidding because of the superior traction over smooth treads on soft roads. A casing that had seen considerable service could be kept in commission for some time if provided with an inner liner and outer protector though it is possible that the combined cost of these would equal that of a new shoe. A disadvantage of inner liners or outer protectors when applied to new casings is that they reduce the flexibility and resiliency of the tire and also that they are apt to generate considerable heat on high speed cars. These accessories are useful if properly

applied and the steel studded outer protector is especially valuable if a trip is contemplated through sections where the highways are rocky.

Q. Name some simple rules relating to the care of tires in general.

A. The following paragraphs are included in the instruction book of a prominent tire manufacturer and as they are based on a wide experience and may be easily committed to memory by those who wish to reduce their tire cost, they are reproduced in full.

Keep the floor of the garage free from oil. Oil softens the rubber and causes it to disintegrate, ruining the tire in a short time. Also see that all inner tubes in the car are kept free from grease and oil and out of contact of metal tools.

When the tire becomes worn more on one side than the other from rutty roads, reverse it. It will last longer. It is a good plan to change the front and rear tires, if they are of the same size, when they begin to show wear. The rear tires always wear out first.

A sprung axle will cause a tire to wear out in a hurry as will poorly lined up front wheels. Always jack up the car when it is to be left standing for any length of time. Keep all the strains off the tires that you possibly can at all times.

Care should be used in "braking" your car and in rounding corners. The owner who does not subject his tires to any unusual strains and keeps them pumped up properly will have but little trouble.

A very important point often overlooked by wheel builders is to paint the outside surface of the rims or part upon which the tire rests. If this has been omitted, steps should be taken at once to have them painted, as rusty rims quickly destroy tires.

Always negotiate car tracks carefully, taking care not to hit a sharp frog or switch member which is apt to cut a tire badly. Never run on car tracks because these may have worn to a sharp or rough edge that will soon cut the rubber. In starting, always engage the clutch lever gently to avoid unnecessary slipping of the rear wheels and when turning corners always disengage the clutch and allow the car to coast around. This will save the differential gear as

well as the tires. Do not bring a car to a stop so near a curb that the tires can scrape against the rough stone in stopping or in starting off again.

If the car is not used during the winter, it is better to remove the tires from the rims, keeping casings and tubes away from the light—the temperature of the room to be about 50 degrees. It will be better to slightly inflate the tubes, as that keeps them very nearly in the position in which they will be used later on. Before the tires are put back, the rims should be thoroughly cleaned, and any rust carefully removed; a coat of shellac is also advised.

Occasionally a tire will apparently puncture without good reason. In such cases, examine the rim and it will probably be found that a bolt head protrudes above the rim surface and has finally worn through the tube. The obstruction should be buffed or filed off until the bolt lies flush with the rim bed.

If the trouble is caused by a bolt being driven too far into the rim, leaving a depression sufficiently sharp and deep to damage the tube, this should be filled in. A compound of pumice stone and coach varnish mixed to the consistency of putty will do the work nicely. Just fill the hole and leave the filling material to dry for an hour or so, and it will become hard.

LESSON THIRTY-SIX

MOTOR CAR EQUIPMENT AND ACCESSORIES

Q. What does the regular equipment of motor cars include?

A. Most automobiles marketed at the present time are equipped as shown at Fig. 311, the accessories furnished by the makers including complete lighting outfit comprising two head lights, two side lights and a tail lamp; a windshield, speedometer (not illustrated) a top cover, and side curtains; some form of alarm signal and a tool outfit for tire restoration and mechanical repairs.

Q. What items of equipment are absolutely necessary?

A. The lights as well as the alarm signal are furnished to meet the laws of most states which say that an automobile must be equipped with adequate lighting equipment and alarm signal. The tool outfit for tire and mechanical repairs is also important. The windshield, top and speedometer are practically necessities but they make for added comfort of operation rather than conducing to safety or complying with the law.

Q. Describe the common method of lighting automobiles.

A. The conventional method of lighting automobiles is by gas and kerosene lamps as outlined at Fig. 312. With a system of this kind, which is furnished on most low and moderate priced cars, the powerful searchlights are designed to burn gas while the side and tail lamps burn oil. The acetylene is sometimes produced by the generator shown at *A* where calcium carbide is acted upon by water to generate the gas, but more often a Prest-O-Lite tank as depicted at *B* containing gas stored under pressure is used. The tail light is shown at *C*, the oil burning side lamp at *D* and the searchlight generally employed is of the form shown at *E*.

Q. Outline advantages of electric lighting, and name the two systems in common use?

A. Electric lighting systems are now furnished on practically

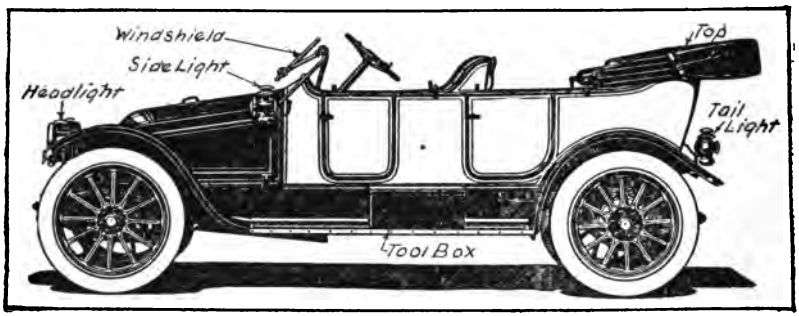


Fig. 311.—Side View of Typical Touring Car Showing Equipment Regularly Furnished by Automobile Manufacturers.

all high grade cars because they possess important advantages of cleanliness and reliability not present in gas or oil lamps. Electric searchlights are very powerful and use but little electric current on account of the efficient tungsten filament lamps used. The lamps are easily lighted from the seat by pushing a switch, whereas the oil and gas lamps must be lighted with matches, often a difficult proposition on a windy day and always a disagreeable task because it is necessary to step in the road and walk around the car to light each lamp in turn. Some users of stored gas have electric gas lighters installed but as this involves the use of a pressure regulator

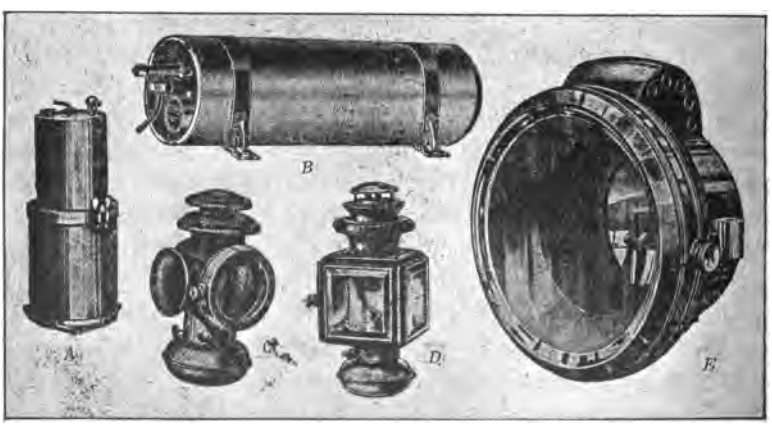


Fig. 312.—Parts of Combination Kerosene and Acetylene Gas Motor Car Lighting System.

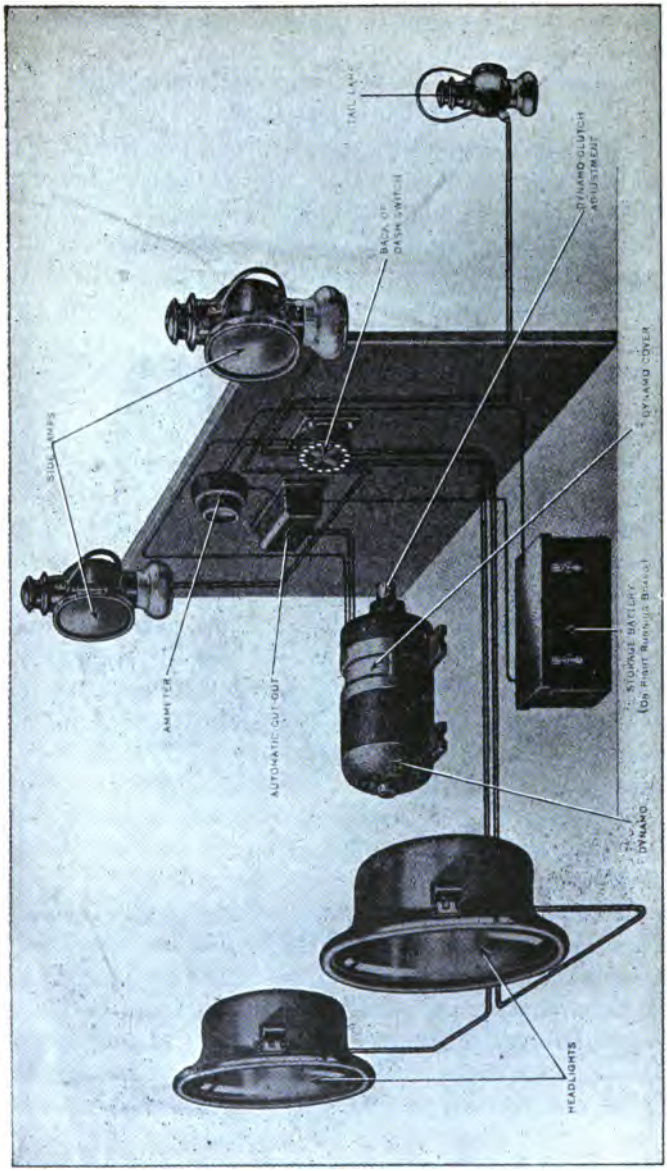


Fig. 313.—Typical Five-Lamp Electric Lighting System Used on Chalmers Touring Cars.

at the gas tank and a complete ignition system composed of an induction coil, battery, push button and wiring besides the special ignition members attached to the lamp burners it is of doubtful advantage over the electric lighting method.

Electric lighting systems may be of two types, that in which the current is supplied from one source, which may be either a mechanical generator such as a dynamo or magneto or a chemical current producer such as a storage battery; and the combination form in which the current is obtained normally from a battery, which however is kept fully charged by a dynamo. The lighting system outlined at Fig. 313 is a typical group composed of five lamps all of which are provided with electric bulbs, though the system illustrated uses combination side and tail lamps in which oil may be burned in case of failure of the electric lighting system. The dynamo is driven by the engine and is connected electrically with the storage battery having an automatic cut-out device inserted in circuit. The function of the automatic cut out is to prevent the battery from discharging through the dynamo if the engine should stop. A switch is provided so either the head light, side lights or tail lights may be put in circuit independently or in combination.

In order to show the utility of electric current and the many conveniences made possible by its use a complete wiring system of a high grade car is shown at Fig. 314. Here the electric current derived from the storage battery is not only used for the usual set of five lamps but it is employed for a dome light, call buzzer, speedometer light, Klaxon horn actuation and for smaller lamps illuminating the gasoline and oil pressure gauges on the dash and the license tag at the rear.

The method of electric lighting in which the generator is employed to charge the storage battery is preferred by most engineers because it insures an unfailing and steady supply of current. If the electricity was derived soley from the generator, it would have a varying value for different engine speeds because the current output of a dynamo depends on the speed at which the armature is rotating. If the engine was run slowly there would not be sufficient light because the current supplied by the generator would be weak; at the other hand, if the power plant was operated at high speed

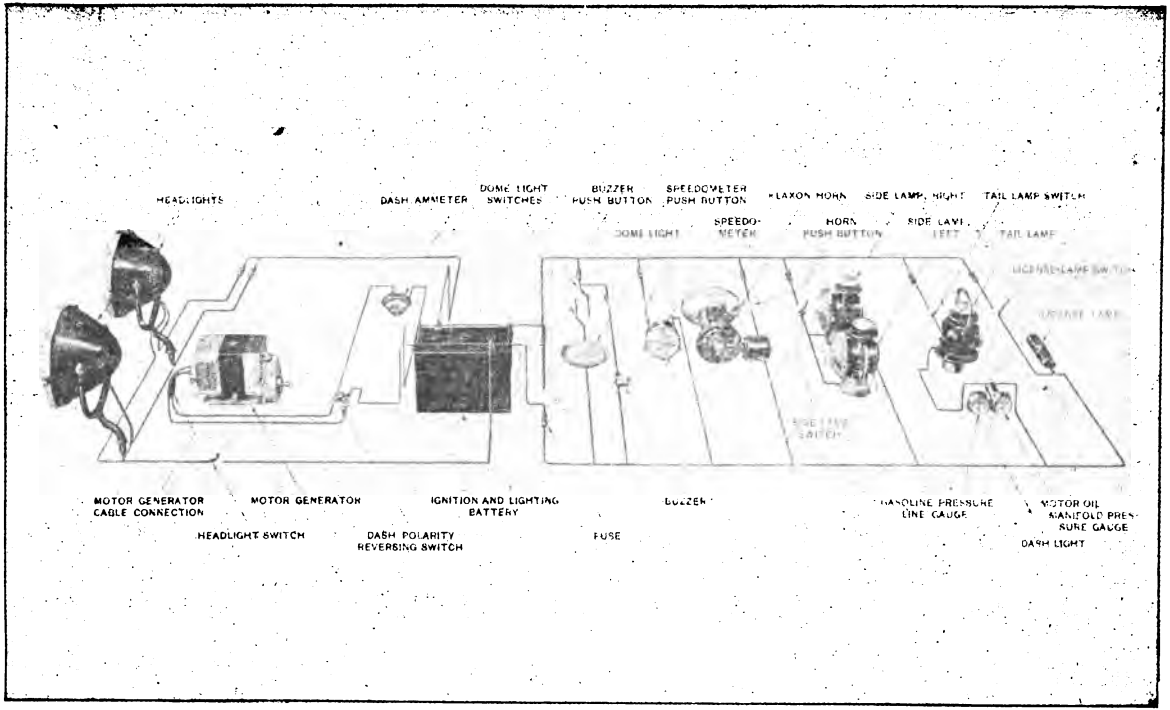


Fig. 314.—How Electric Current is Applied to Advantage for Lighting, Operating Warning Signals and Other Uses on the Packard Automobile.

the generator might produce sufficient current to burn out the lamp filaments. If the current is taken from a storage battery alone, this becomes exhausted in a short time and needs frequent recharging. By combining the two systems of current production, the dynamo is employed to keep the battery properly charged, and as the storage cells are always at full capacity it delivers a steady current of the proper voltage for the lamps.

Q. What are the principal types of automobile warning signals?

A. Automobile warning signals are usually in the form of a horn or whistle, though sirens, electric buzzers and mechanical horns

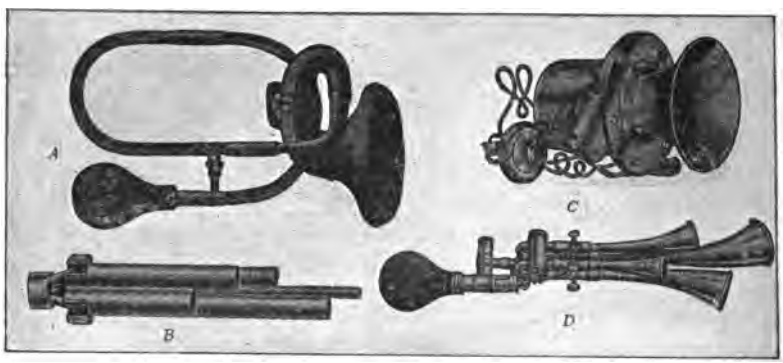


Fig. 315.—Principal Forms of Automobile Warning Signals.

have received wide application of late. The bulb horn shown at *A*, Fig. 315, is a cheap and satisfactory signal for city use, but it is not powerful enough to carry the sound any distance, which is necessary when touring. The operation of a horn of this character is simple, a pressure of the hand on the rubber bulb serving to send a draft of air past a reed located in the horn member.

The exhaust whistle shown at *B* is attached to the exhaust pipe by some form of valve which will cause the gas to pass through this horn instead of through the muffler when desired. As four whistles of varying size and length are provided the device will emit a pleasing musical tone which varies in intensity according

to the velocity of the exhaust gas which in turn depends upon the speed of the engine.

The form of electrical horn generally used is shown at *C*. This is operated from the ignition or lighting battery current which rotates a small motor that acts on a diaphragm by means of a cam provided with a large number of points so the diaphragm is caused to vibrate very fast, and produces a discordant shrieking note that can be heard a long distance away.

The bulb horn shown at *D* has four independent reeds which are brought into action progressively by a simple pneumatic shutter so the series of impulses of air produced by squeezing the bulb will cause the device to give a musical warning sound like a bugle call. The electrically operated horn will throw the warning note farther ahead than any of the others, but the exhaust whistle is superior to the bulb horn. The types of warning signals that have been evolved are legion, but those shown are representative and practical and show the principal forms.

Q. Why are speed indicators valuable?

A. Speedometers, which indicate the velocity of the car in miles per hour, are valuable in enabling the motorist to regulate his speed according to the law. As most of these devices are provided with trip and season odometers which indicate the distance actually traveled the device provides a useful check on the life of tires, gasoline and oil consumption and general service the car is capable of giving A speedometer is also useful in following routes given in various road guide books. A typical speed indicator and clock combination is shown at Fig. 316-A.

Q. What value have tire chains?

A. When plain tread tires are used it is necessary to provide some means by which greater traction or adhesion on wet or slippery roads may be obtained than would be the case if only the smooth rubber and road surface came in contact. The simplest and cheapest method of obtaining this end is by means of anti-skid chains, as shown at *B*, Fig. 316. These not only insure proper traction on unfavorable highways but also provide positive control when the brakes are applied because they prevent skidding.

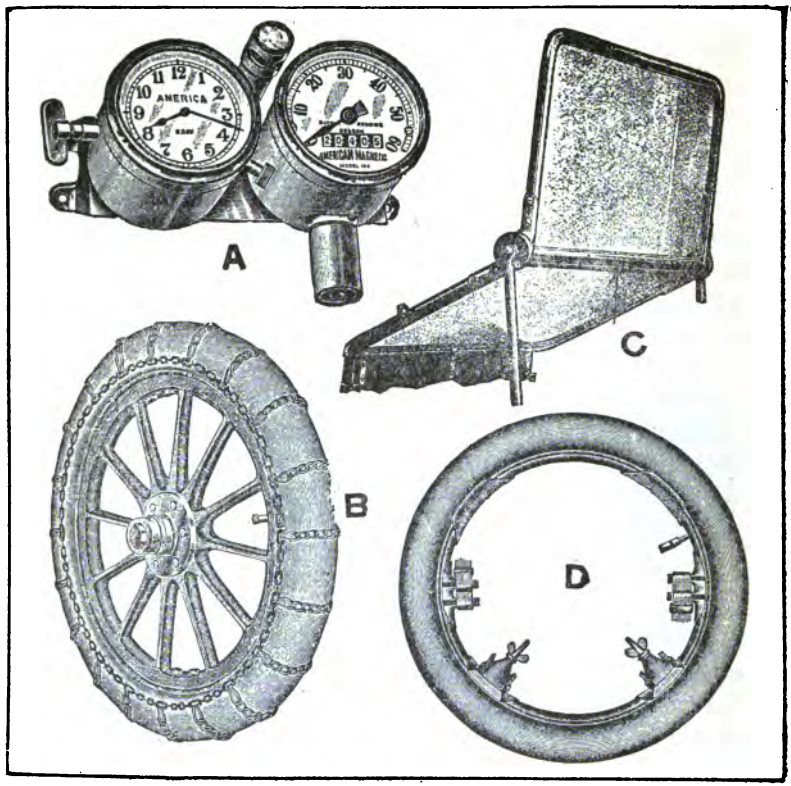


Fig. 316.—Some Useful Accessories for Motor Cars.

Q. What is the wind shield?

A. The wind shield is a frame of metal tubing in which are placed lights of plate glass, so the operator and passengers may be shielded from the dust or cold wind without interfering with the vision. A typical wind shield is shown at *C*, Fig. 316. The frame may also be made of wood or a light metal frame covered with leather and having celluloid pieces instead of glass may be used.

Q. What is the Stepney emergency rim?

A. The Stepney spare wheel is a rim adapted to carry a fully inflated tire and having lugs and anchorage members by which it

may be quickly attached to the rim of a wheel having a flat tire without removing the defective tire. This device is not widely used at the present time because quick detachable and demountable rims have been developed that permit one to make a tire change in but very few minutes. A spare rim of this form with tire in place showing the attaching lugs is depicted at *D*, Fig. 316.

Q. What are shock absorbers, and how do they work?

A. Shock absorbers are devices intended to prevent harsh action of chassis supporting springs, either by providing some retarding means to keep the spring from working too fast, deflecting too much or act as a check to prevent too rapid rebound after deflection. The principal forms of shock absorbers are outlined at Fig. 322. The Ames device is a supplementary laminated leaf spring fitted on top of a regular semi-elliptic form to prevent rapid rebound. The J. M. shock absorber is a type designed to replace the usual spring shackle and operates by providing sensitive springs to take the shocks produced by minor road irregularities. Devices of this nature are not true shock absorbers but are more in the nature of auxiliary springs. The Sager device is a simple coil spring attached to frame and axle. These are supplementary members which act to retard rapid movements of the main spring. The Gabriel device is a rebound check that prevents a rapid return of the spring after deflection. The Connecticut shock absorber has a series of leaf springs in a housing attached to one arm to retard the motion of a cam piece attached to the other arm joined to the spring. The Truffault-Hartford comprises friction pads at the joint of levers attached to the spring and frame respectively. These friction pads prevent rapid axle movement, either on deflection or rebound. The Flentje shock absorber is a hydraulic form in which too rapid spring movement is prevented by the dash pot action of a piston provided with small passages working in a cylinder filled with glycerin. The auxiliary springs such as the Sager are very useful if rough riding is caused by the main springs being weak. The J. M. type provides easy riding when the main supporting springs are too stiff. The

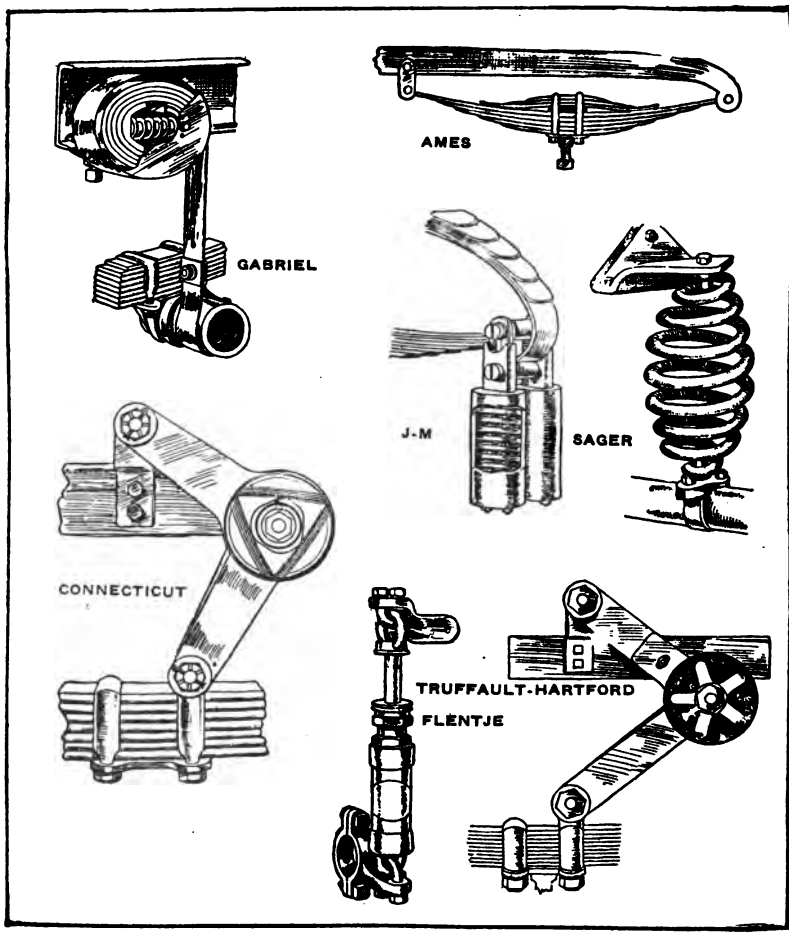


Fig. 322.—Principal Forms of Shock Absorbers and Auxiliary Springs.

other forms outlined are used to steady the action of the springs regardless of the spring strength.

Q. Describe tool equipment for mechanical repairs.

A. A kit of tools suitable for general adjustments around a small car is shown at Fig. 323, while a more complete outfit adapted for any size car and for making road repairs of any nature is shown

at Fig. 324. This outfit includes double ended S wrenches to fit standard nuts and bolts; an adjustable Stilson wrench for pipe and round rods; a monkey wrench which can be adjusted for various size nuts; a set of four files, including round, three cornered, half round, and flat, with a suitable handle; a soldering copper which fits the file handle and some wire solder; three pairs of pliers, one of these being provided with cutting jaws, and various small tools such as a chisel and punch set, a cotter pin extractor and small three cornered scraper.

Other tools that may be added to advantage if a motorist is possessed of any mechanical skill are shown at Fig. 325. The pliers at *A* are specially made for inserting cotter pins. The punch and chisel set at *B* can be included to advantage if these tools are not already incorporated in the main tool outfit. The assortment is useful as it includes a double end offset screw driver and small adjustable bicycle wrench in addition to the punches, chisels and drifts. The set of scrapers shown at *C* are used for removing carbon from the interior of the motor cylinder by inserting through valve caps or spark plug holes where the motor construction permits. The socket wrench depicted at *D* is useful in removing spark plugs when these members fit recessed valve caps or cylinder castings. The scrapers illustrated at *E* are used in refitting bearings and are tools for mechanic and repairman rather than the average motorist. The very complete socket wrench outfit shown at *F* is also useful for any one who does much repairing because it permits the removal of nuts in very inaccessible places. Tubular sockets are provided that will fit practically any standard nut or bolt used in automobiles regardless of how inaccessible they are located. A number of standard size double end socket wrenches and Tommy bar as shown at *G* are useful if the larger set illustrated at *F* is not at hand. The brush at *H* is provided for cleaning spark plugs and other parts of soot or carbon and also includes small pieces of spring stock for scraping dirt out of corners not reached by the brush.

Q. Name spare parts and supplies that can be carried on car when touring.

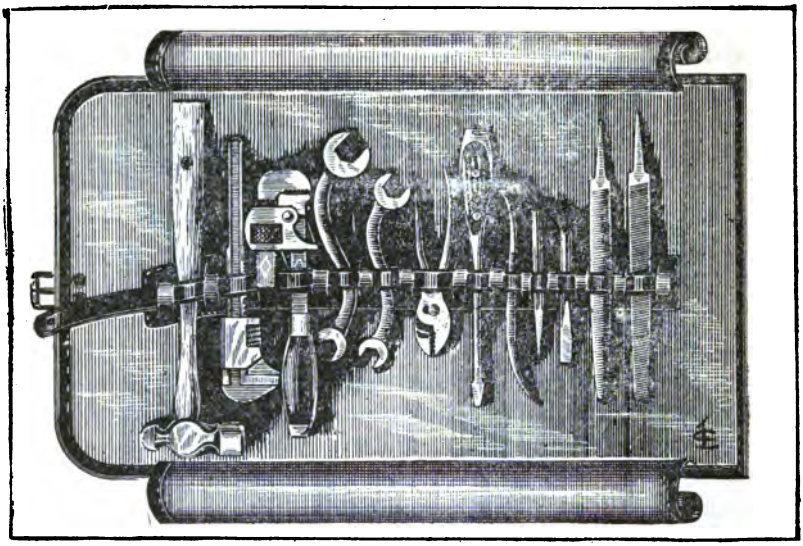


Fig. 323.—Typical Small Tool Kit Suited for Ordinary Motor Car Repairs.

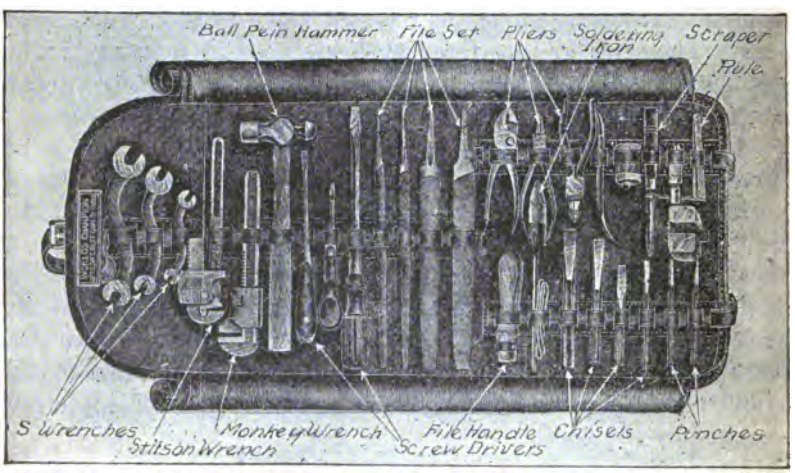


Fig. 324.—Complete Tool Outfit for Repairing Motor Car Mechanism That Occupies but Little Space.

A. A group of standard small parts arranged in tin boxes that are adapted for most makes of automobiles is shown at Fig. 326. The box at *A* contains spring or lock washers, that at *B* castellated nuts in assorted sizes. The box at *C* has an assortment of regular standard nuts, the container *D* is full of assorted split or cotter pins, that at *E* contains set screws. An assortment of standard cap screws and bolts is shown at *F* and a box full of assorted taper pins is illustrated at *G*. The supplies shown at Fig. 327 may be carried on a car if the tour is to go to sections remote from repair shops. Some of the appliances are useful under all conditions. The hydrometer shown at *A*, Fig. 327, is employed for testing the solution of storage batteries. A combination syringe and hydrometer shown at *B* may be used to advantage in its place if an electric lighting or starting system is included in the car equipment because it enables the motorist to test the specific gravity of the electrolyte in the storage battery from time to time and thus determine the amount of current available. The hydrometer shown at *C* is used in testing fuels. The folding water pail shown at *D* takes but little space and is a very convenient receptacle for filling the radiator from any wayside stream and also for holding water for washing the hands when repairs have been made. If an electric lighting system is fitted spare bulbs for all lamps should be carried. A typical Edison base tungsten filament lamp is illustrated at *E*. The valve grinding tool shown at *F* is more properly a garage or repair shop tool though many motorists who look after their own cars find it valuable when grinding in the valves to a new seating. The spring provided with the valve grinding tool is placed under the valve head to raise the valve from its seat when the weight holding the valve to its seat is relieved, while the small can contains abrasive valve grinding compound.

The hand oil can at *G* and bracket by which it may be attached to the dash is standard equipment. When sufficient current is available as when a storage battery is supplied for lighting or starting, the small trouble lamp and length of wire shown at *H* can be used to illuminate various parts of the mechanism when making repairs after dark. A lamp of this nature is practically a necessity because it is dangerous to make adjustments where gasoline

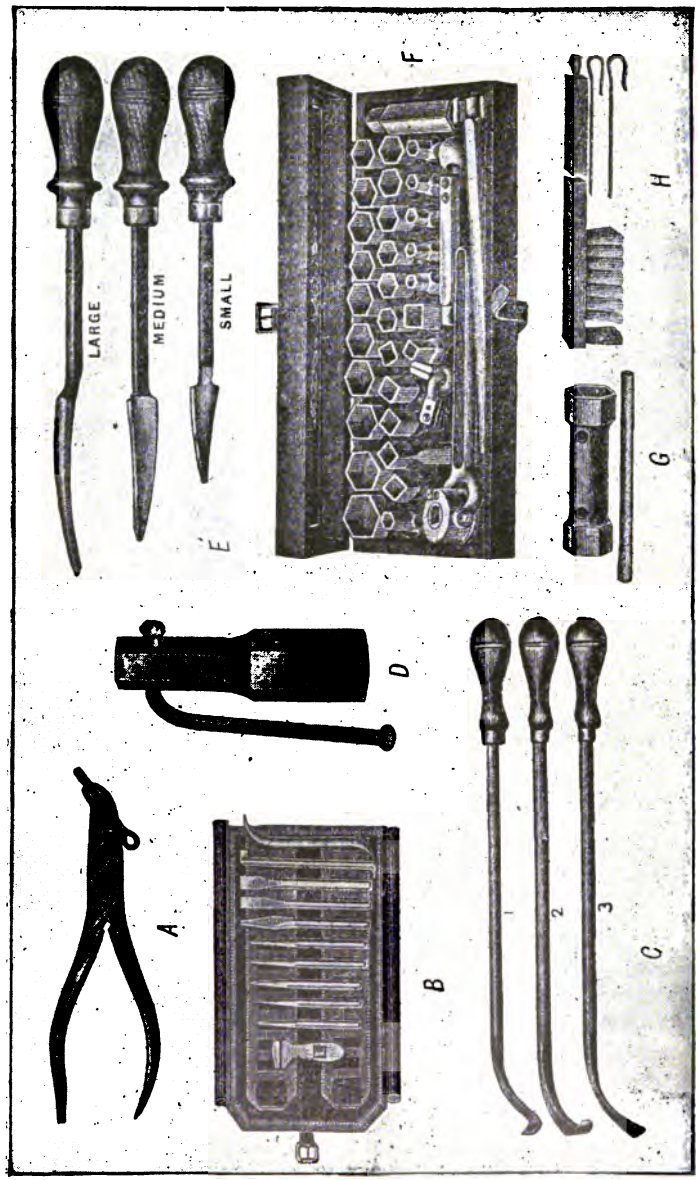


Fig. 325.—Useful Tools that Facilitate Motor Car Repairs.

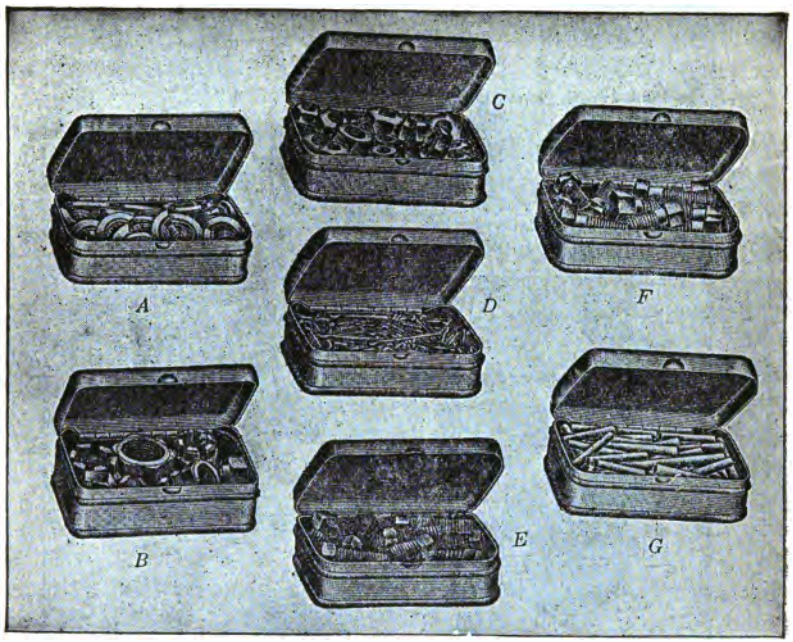


Fig. 326.—Spare Washers, Nuts, Bolts, etc., That Can be Used to Advantage for Replacing Lost Members on All Makes of Cars.

fumes are present by the light of an oil lamp. The syringe or oil gun shown at *I* is of value when one wishes to inject oil or grease into some inacessible oil hole and for drawing gasoline from the tank for priming the engine or cleaning off a tire inner tube before patching. The small vise shown at *J* may be screwed to the running board or work bench and will prove invaluable when needed. The small torch depicted at *K* burns gasoline and is a useful adjunct to the tool kit shown at Fig. 324 as it will supply heat for the soldering iron.

Q. How are tools, spare tires, clothing, etc., carried on the average automobile?

A. In many cars, especially those with the gasoline tank under the front seat, there is not sufficient room for stowing away all the tools, etc., needed when touring so various forms of trunks and cases

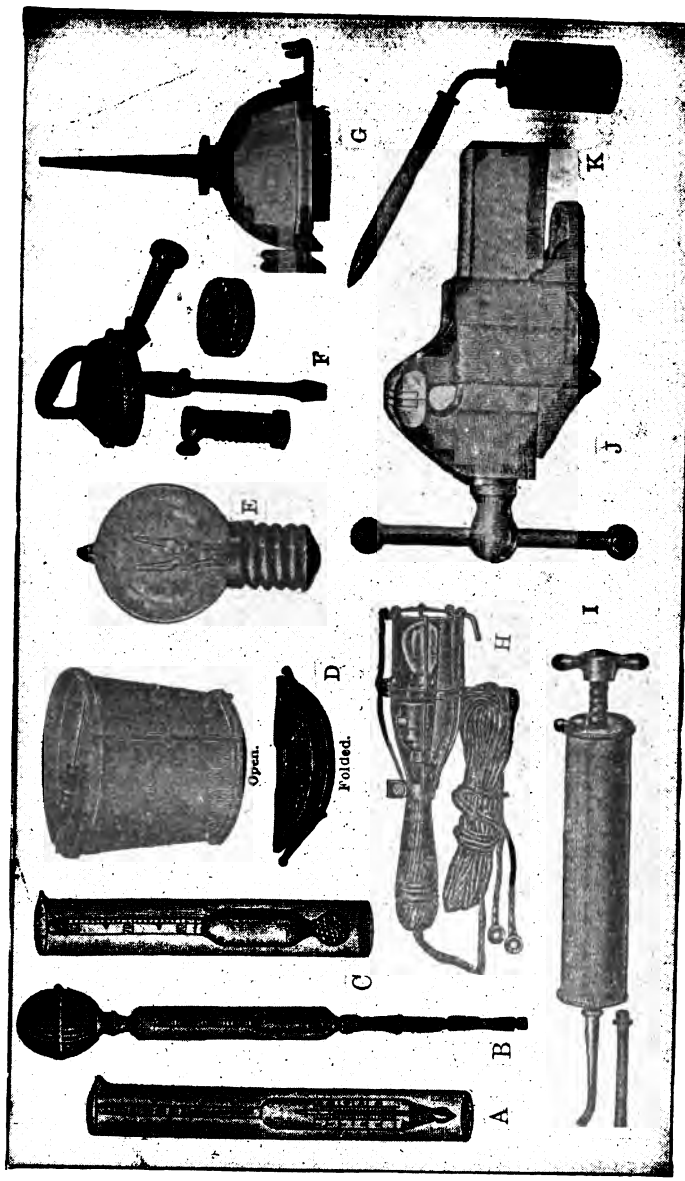


Fig. 327.—Useful Tools and Appliances to Assist in Caring For or Repairing Automobile Mechanism.

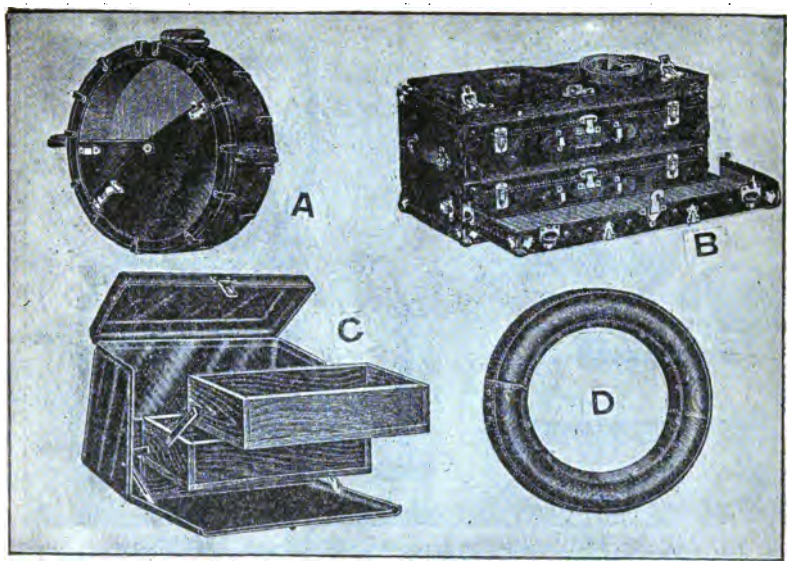


Fig. 328.—Containers for Carrying Tools, Spare Parts, etc., Designed Especially for Motor Car Service.

are made for the purpose as outlined at Fig. 328. The tire trunk shown at *A* is intended for attachment to the running board and will fit inside of the tire casings usually carried at that point. It provides considerable space in its interior for inner tubes, tire repair outfit or other supplies. The trunk at *B* is designed for clothing and it carries two individual dress suit cases, protecting them thoroughly from the dirt. It may be carried on a trunk rack at the back of the car. The box at *C* is designed for attachment on a running board and the drawers may be used to advantage in carrying tools or spare parts of that nature. When spare outer casings are carried it is customary to enclose these in a protecting cover of enameled duck or leather as outlined at *D*.

Q. Enumerate some other useful accessories that will complete equipment of average car.

A. A car that is operated in traffic a large part of the time can be provided with a front bumper or fender as shown at *A*, Fig. 329.

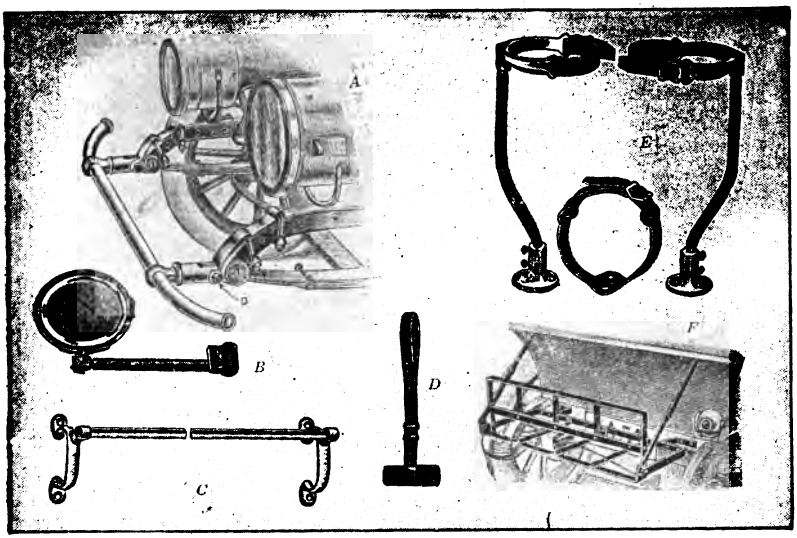


Fig. 329.—Various Useful Devices to Complete Motor Car Equipment.

to advantage as these protect the lamps and radiator from damage in event of collision with any other vehicle. The mirror at *B* is attached to the side of the windshield and provides a rear view appreciated by some drivers. The robe rail at *C* is a convenience that can be fitted to the back of the front seats at little expense if the car is not already provided with one. The strap and holder shown at *D* will keep the starting crank from rattling and as the handle is thrust in the small case when not in use that member is kept clean at all times. The usual set of brackets attached to the running board for carrying a spare tire casing is shown at *E*. A folding trunk rack for use in carrying trunk shown at *B*, Fig. 328, or other baggage is clearly outlined at *F*. While these accessories are not absolutely necessary they are very convenient and contribute materially to the pleasure of motoring.

NOTE.—For complete discussion of electric lighting and self-starting systems see "Automobile Starting, Lighting, and Igniting Systems." By Victor W. Page. Price, $1.50.

LESSON THIRTY-SEVEN

DEVELOPMENT OF 1917 AUTOMOBILE DESIGN

Q. Name some of the latest improvements in design.

A. Prominent among these may be mentioned the eight and twelve cylinder V motors, the universal adoption of electric starting and lighting systems, the use of cantilever springs, and wide introduction of the Stewart vacuum feed fuel system.

Q. What are the advantages of the eight cylinder V motor over the "all-in-line form"?

A. The announcement of a prominent motor-car maker in the late fall of 1914 that it was to market an eight cylinder motor vehicle in 1915 created a furor in the automobile trade. This type of motor appealed strongly to the motorist as well as to the manufacturer, as is evidenced by the announcement of the production of eight cylinder models by more than a dozen makers. That manufacturers of engines anticipate a general demand for eight cylinder types can be judged by the fact that all of the leading engine builders are developing eight cylinder engines. Those who have followed the development of the gasoline engine will recall the arguments that were made when the six cylinder motor was introduced at a time that the four cylinder type was considered standard. The arrival of the eight cylinder has created similar discussion of its practicability.

The reason the V type shown at Fig. 330-A is favored is that the "all-in-line form" which is shown at Fig. 330-B is not practical for motor vehicles because of its length. Compared to the standard four cylinder engine it is nearly twice as long and it required a much stronger and longer crank shaft. It will be evident that it could not be located to advantage in the automobile frame. These

mitigating factors are eliminated in the V type eight cylinder motor, as it consists of two blocks of four cylinders each, so arranged that one set or block is at an angle of forty-five degrees from the vertical center line of the motor, or at an angle of ninety degrees with the other set. This arrangement of cylinders produces a motor that is no longer than a four cylinder engine of half the power would be.

Q. Is the eight cylinder V engine a new or untried type?

A. The eight cylinder V type engine is not a new design by

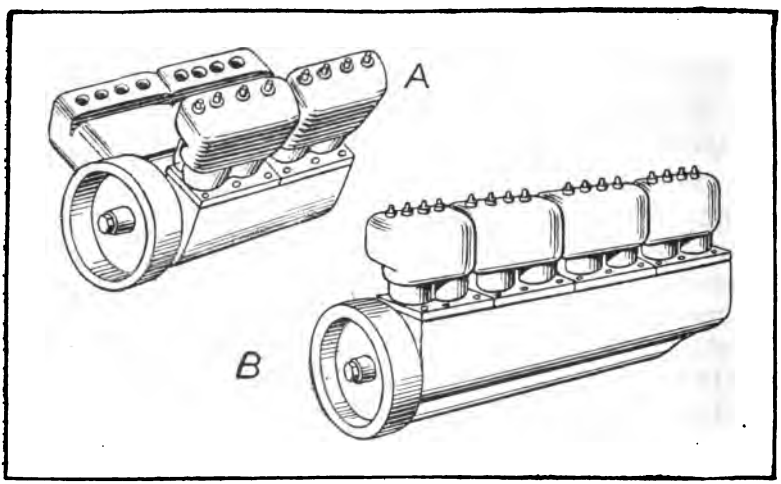


Fig. 330.—Types of Eight Cylinder Engines Showing the Advantage of the V Method of Cylinder Placing.

any means, although it is not generally known to automobilists. It has been a standard power plant for aeroplanes for many years, leading exponents being the Antoinette, the Woolsley, the E. N. V. in Europe and the Curtiss in the United States. Messrs. De Dion-Bouton, a leading French automobile manufacturer, is credited with being the first to produce an eight cylinder motor as a commercial proposition. Many racing cars have been built with eight cylinder motors, notably the Rolls-Royce, the Darracq and Winton. The eight cylinder V type has also been widely used in

racing motor boats and gasoline propelled railway coaches. It was not a surprise, therefore, to those who were familiar with internal combustion engineering when the eight cylinder engine was applied for automobile propulsion.

Q. What are the real advantages of the eight cylinder engine?

A. Apparently there is considerable misconception as to the advantage of the two extra cylinders of the eight as compared with the six cylinder. It should be borne in mind that the mul-

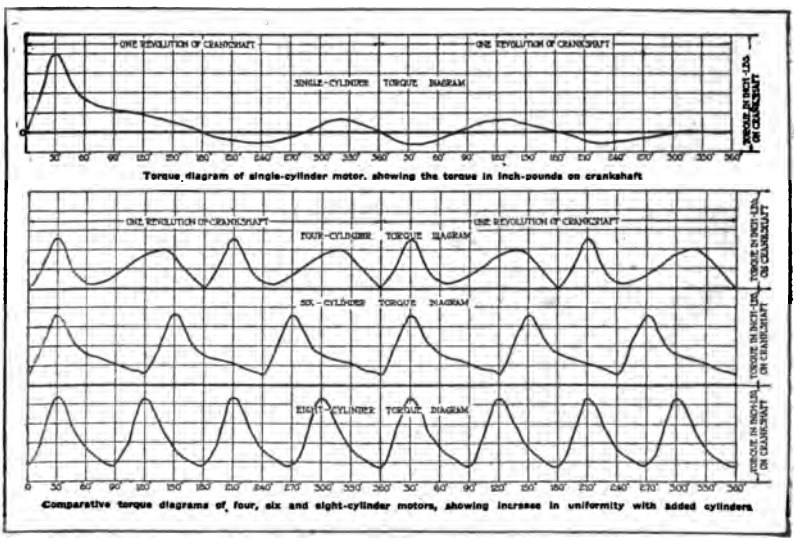

ONE REVOLUTION OF CRANKSHAFT
SINGLE-CYLINDER TORQUE DIAGRAM
Torque diagram of single-cylinder motor, showing the torque in inch-pounds on crankshaft
FOUR-CYLINDER TORQUE DIAGRAM
SIX-CYLINDER TORQUE DIAGRAM
EIGHT-CYLINDER TORQUE DIAGRAM
Comparative torque diagrams of four, six and eight-cylinder motors, showing increase in uniformity with added cylinders

Fig. 331.—Curves Showing Torque of Various Engine Types Demonstrate Graphically Marked Advantage of the Eight Cylinder Type.

tiplication in the number of cylinders noticed since the early days of automobile development has not been solely for increasing the power of the engine, but to secure a more even turning movement, greater flexibility and to eliminate destructive vibration. The ideal internal combustion motor would be that which more nearly conforms to the steady running produced by a steam turbine or electric motor. The advocates of the eight cylinder engine bring up the item of uniform torque as one of the most important advan-

tages of the eight cylinder design. A number of torque diagrams are shown at Fig. 331. While these appear to be deeply technical, they may be very easily followed when their purpose is explained. At the top is shown the torque diagram of a single cylinder motor of the four cycle type. The high point in the line represents the period of greatest torque or power generation, and it will be evident that this occurs early in the first revolution of the crank shaft. Below this diagram is shown a similar curve except that

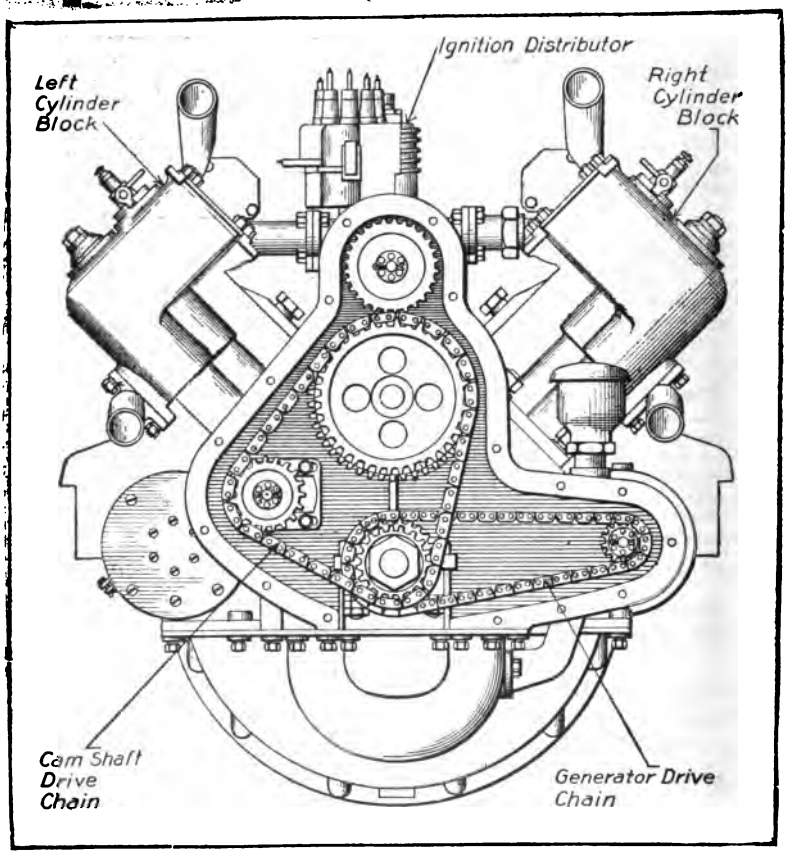


Fig. 332.—Front View of the King Eight Cylinder V Engine with Cover Removed from Timing Gear Case to Show Use of Silent Chains for Driving Camshaft and Auxiliary Devices.

it is produced by a four cylinder engine. Inspection will show that the turning moment is much more uniform than in the single cylinder; similarly, the six cylinder diagram is an improvement over the four, and the eight cylinder diagram is an improvement over the six cylinder.

Q. Why is better torque obtained with an eight cylinder engine than with a four or six?

A. The reason that practically continuous torque is obtained

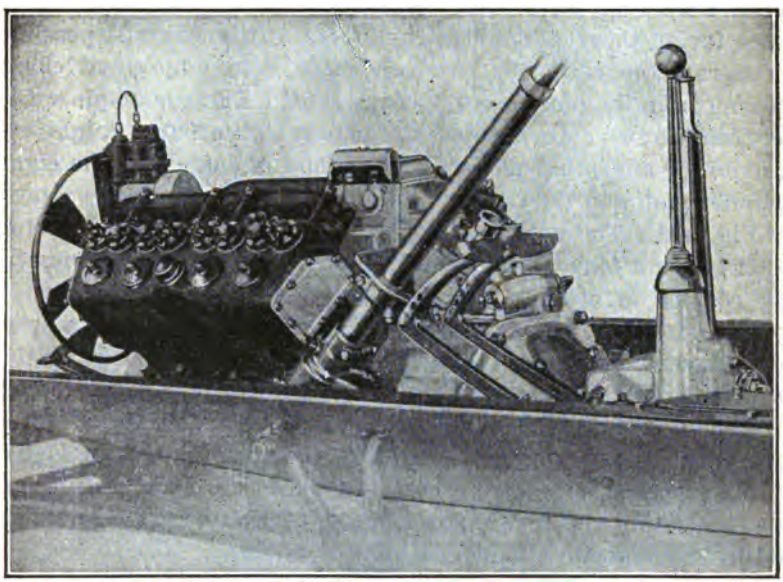


Fig. 333.—Method of Installing Cadillac Eight Cylinder Engine in Motor Car Frame.

in an eight cylinder engine is that one cylinder fires every ninety degrees of crank shaft rotation, and as each impulse lasts nearly seventy-five per cent. of the stroke, one can easily appreciate that an engine that will give four explosions per revolution of the crank shaft will run more uniform than one that gives but three explosions per revolution, as the six cylinder does, and will be twice as smooth running as a four cylinder, in which but two

explosions occur per revolution of the crank shaft. The comparison is so clearly shown in graphical diagrams that further description is unnecessary.

Q. How does an eight cylinder engine differ mechanically from a four or six?

A. The front view of a typical eight cylinder engine with the cover removed from the timing gear case is outlined at Fig. 332. In this engine the cylinders are cast in blocks of four and are of the L head type, the valves being on the inside of the cylinder block facing those of the other cylinders. This makes it possible to operate the valves by one cam shaft, driven by silent chain gearing from the pinion on the crank shaft. There is ample space between the two cylinder blocks to mount the carburetor, ignition distributor and other parts. The method of installing the eight cylinder motor in the Cadillac automobile frame is clearly shown at Fig. 333. The only point in which an eight cylinder motor differs from a four cylinder is in the arrangement of the connecting rod, as in many designs it is necessary to have two rods working from the same crank pin. This difficulty is easily overcome in some designs by staggering the cylinders and having the two connecting rod big ends of conventional form side by side on a common crank pin. In other designs one rod is a forked form and works on the outside of a rod of the regular pattern. Still another method is to have a boss just above the main bearing on one connecting rod to which the lower portion of the connecting rod in the opposite cylinder is hinged.

As the eight cylinder engine may actually be made lighter than the six cylinder of equal power, it is possible to use smaller reciprocating parts, such as pistons, connecting rods and valve gear, and obtain higher engine speed with practically no vibration. The firing order in nearly every case is the same as in a four cylinder except that the explosions occur alternately in each set of cylinders. In prevailing practice the sequence is 1-3-4-2. The firing order of an eight cylinder motor is apt to be confusing to the motorist, especially if one considers that there are eight possible sequences. The majority of engineers favor the alternate firing

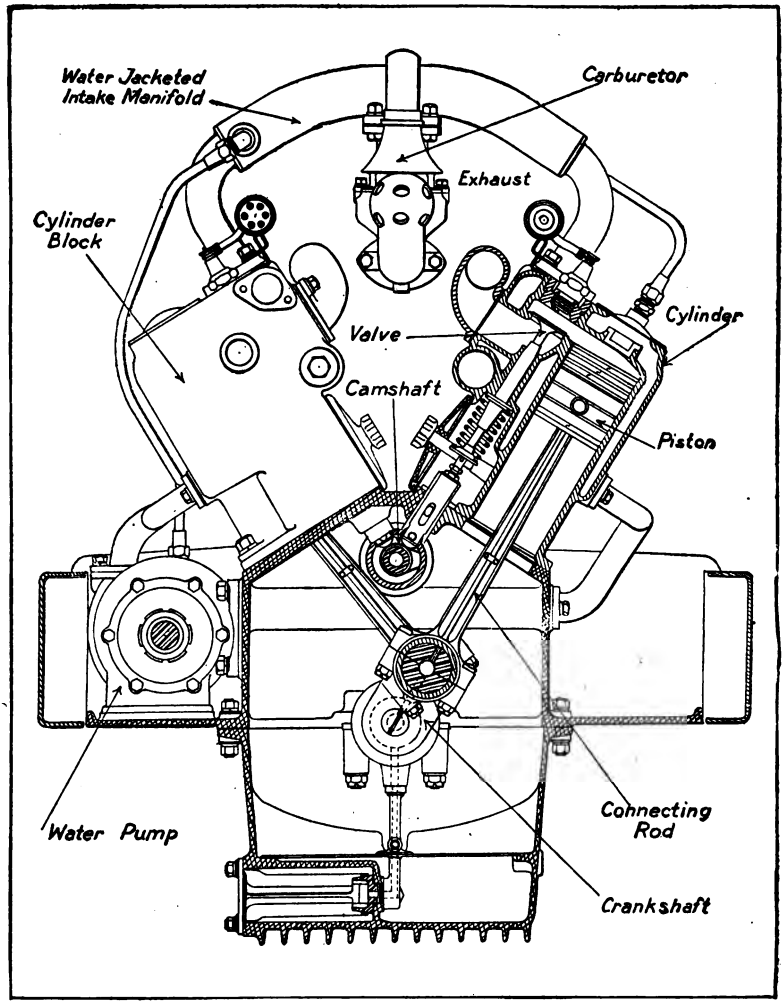


Fig. 334.—Sectional View Through End Section Through Packard Twin Six Motor, Showing Arrangement of Parts and Narrow Motor Possible by 60-degree Placing.

from side to side. This is given by several manufacturers as follows: 1-4-5-2-7-6-3-8. Another firing order, 1-8-3-6-4-5-2-7; still another, 1-6-3-5-4-7-2-8. Some makers call the left front cylinder,

or that nearest the radiator, No. 1, and the opposite cylinder the No. 8. No difficulty is experienced in an eight cylinder engine either in the carburetion or in firing the charge. In six cylinder engines some difficulty is apt to be experienced in securing proper carburetor action, but in an eight the problem is as simple as in the four cylinder engine.

Q. Describe the Packard twelve cylinder V engine.

A. One of the first makers to announce a twelve-cylinder car for the 1916 season is the Packard Motor Car Company of Detroit, Mich., which is building a high-speed motor incorporating all recent features of design in securing light reciprocating parts, large valve openings, etc. The twelve-cylinder motor incorporates the best features of high-speed motor design and there is no need at this time to discuss further the pros and cons of the twelve-cylinder versus the eight or six, because it is conceded by all that there is the same degree of increase of steady power application in the twelve over the eight as there would be in the eight over the six. The question resolves itself into having a motor of high power that will run with minimum vibration and that produces smooth action. It should be remembered that if an eight-cylinder engine will give four explosions per revolution of the fly-wheel a twelve-cylinder type will give six explosions per revolution, and instead of the impulses coming 90 degrees crank travel apart, as in the case of the eight-cylinder, they will come but 60 degrees of crank travel apart in the case of the twelve-cylinder. When one realizes that the actual duration of the power stroke is considerably greater than 120 degrees crank travel, it will be apparent that the overlapping of explosions must deliver a very uniform application of power.

The dimensions of the new Packard motor are 3″ bore by 5″ stroke, giving a total piston displacement of 424 cubic inches. The motor will attain a speed of 3,000 R.P.M., or more if necessary, although the multiplicity of explosions produces so much power at the low motor speeds that the high range of speed will be needed only when extreme conditions are encountered. The pistons are of aluminum alloy and the connecting rods are machined all over

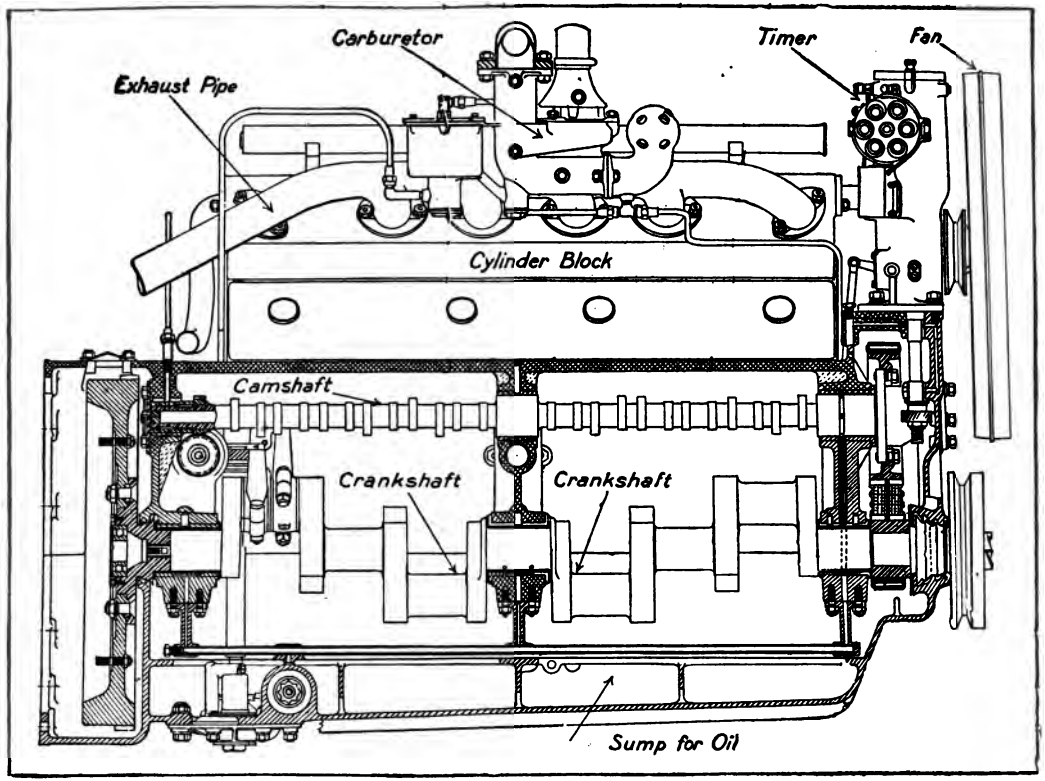


Fig. 335.—Longitudinal Section Through Packard Twin Six Motor Depicting the Three Bearing Crankshaft, Method of Attaching the Connecting Rods Side by Side on Crank Pins and Oilways for Bearings.

in order to have small reciprocating weight. The piston weighs but 17 ounces complete with rings, and the upper half of the connecting rod, which is considered a reciprocating mass, weighs but 8.5 ounces, this making a very small total mass of 1 pound 9.5 ounces. Knowing that the vibration which is present in the six-cylinder is due to the weight of pistons, etc., it will be apparent that if this weight is lessened, as it is in the "Twin Six" design, a much smoother running motor will be obtained. One may say that the twelve-cylinder is an attempt to combine the advantages of the six and eight and to simultaneously eliminate some of the disadvantages of both types. While this is true to only a limited extent, it is apparent that for very powerful engines the twelve-cylinder will have a logical field.

The Packard motor has two block castings, consisting of six cylinders each, set on an aluminum crank case, with the cylinder center lines 30 degrees each side of the vertical motor center line, which gives an included angle of 60 degrees between the two cylinder center lines. This arrangement gives the best torque, which is obtained with even intervals between the explosions. The valves are placed between the cylinders in the ordinary "L" fashion, but they are more accessible than in the eight-cylinder because the narrowness or reduction of width possible by the 60-degree placing of the cylinders allows the generator, starting motor, water pump and other attachments to be mounted alongside of the engine crank case just as in the ordinary four-cylinder engine. This clears the valves of all obstructions and the carburetor is placed high enough to be easily reached itself. Ignition is by battery and coil, two timer-distributors being used, one for each block of six cylinders.

In a recent test, the Packard motor used but one gallon to eleven miles, which is very good mileage for an engine of that horse power. To allow the motor to be used at continued high speed, a high-pressure oiling system is essential. The oil is carried up from the crank pins to the piston pins by pipes lying inside of the channel of the "H" section of the connecting rods. There are but three main crank shaft bearings, this being considered sufficient for the short length of the crank shaft. Besides

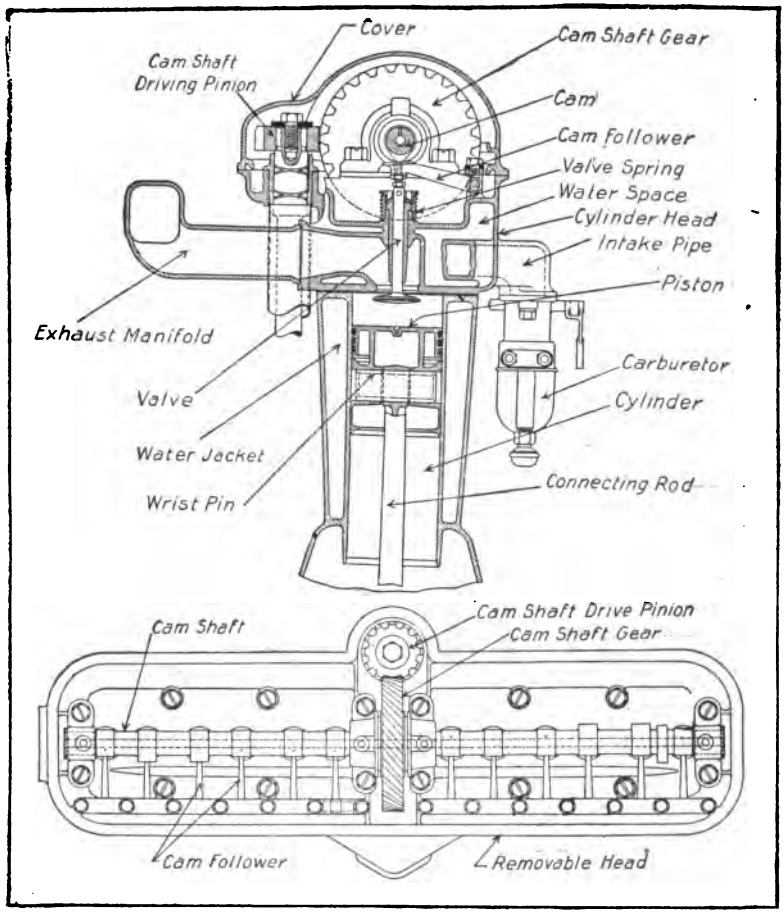


Fig. 336.—Sectional View of the Weidely Motor Showing Method of Operating Valves by Overhead Camshaft.

the crank shaft and piston pin leads, oil under pressure is distributed to the cam shaft, generator shaft, air and oil-pump shafts and the timer shaft. Overflow from the generator shaft cares for the silent chain at the front which drives the camshaft and auxiliary units placed at the side of the motor.

It is stated that the marked advantages of the motor using

twelve cylinders is found in actual road operation, where it is possible to run the car at a walking pace on the high gear, and it is also possible to accelerate from this low speed to a speed of 30 miles per hour in twelve seconds on a level cement road on the high speed ratio. The car will attain a road speed of over 60 miles per hour with no perceptible motor vibration. A National

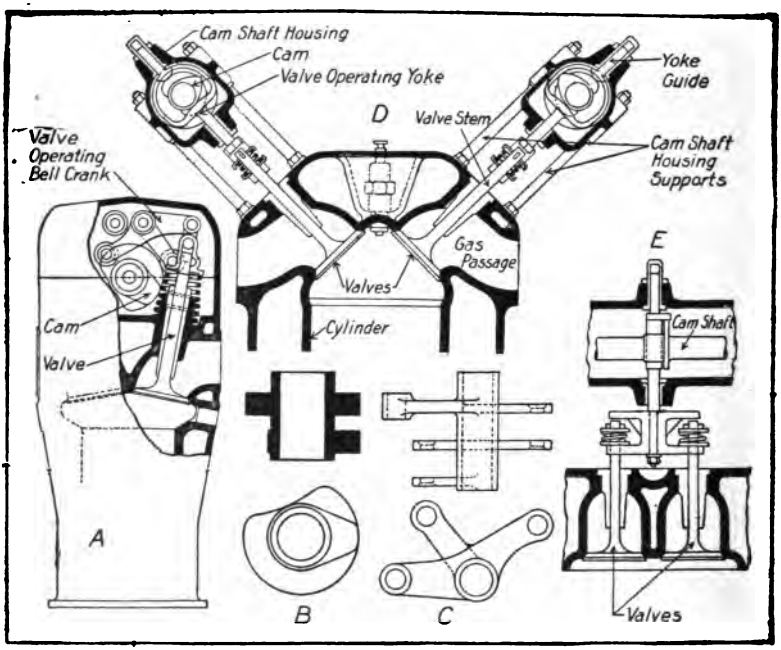


Fig. 337.—Two Methods of Operating Valves by Positive Cam Mechanism which Closes as well as Opens Them.

twelve-cylinder engine will also be offered in 1916, and several other makers of high-powered cars are said to be considering this type of engine.

Q. What is the detachable cylinder head motor?

A. There is a growing tendency on the part of the designers to use the detachable cylinder head construction that was first introduced in a commercial way on multiple cylinder automobile

engines by Henry Ford. A new design which is shown at Fig. 336 incorporates not only the detachable head feature having valves directly in the head, but also includes an overhead cam shaft with practically direct actuation of the valve stem. The construction of the valve operating member can be clearly understood by referring to the illustration at the top of Fig. 336. As the engine outlined is a six cylinder form, twelve valves are carried in the removable head member, which means that the cam shaft must have twelve cams. The cam shaft is driven at the central point by means of a worm or spiral pinion which drives a larger spiral gear attached to the cam shaft. In order to relieve the valve stem of side thrust, a cam follower is interposed between the cam and the top of the valve stem.

Q. What are springless valves and what are their advantages?

A. Springless valves are the latest development on French racing cars and it is possible that the positively operated types will be introduced on pleasure cars also. Two makes of positively actuated valves are shown at Fig. 337. The positive valve motor differs from the conventional form by having no necessity for valve springs, as a cam not only assures the opening of the valve, but also causes it to return to the valve seat. In this respect it is much like the sleeve valve motor where the uncovering of the ports is absolutely positive. The cars equipped with these valves were a success in long-distance auto races. Claims made for this type of valve mechanism include the possibility of a higher number of revolutions and consequently greater engine power. With the spring controlled, single cam operated valve a point is reached where the spring is not capable of returning the valve to its seat before the cam has again begun its opening movement. It is possible to extend the limits considerably by using a light valve on a strong spring, but the valve still remains a limiting factor in the speed of the motor.

Q. Describe typical springless valve designs.

A. A part sectional view through a cylinder of an engine designed by G. Michaux is shown at Fig. 337-A. There are two

valves per cylinder inclined at about ten degrees from the vertical. The valve stems are of large diameter, as owing to positive control, there is no necessity of lightening this part in an unusual degree. A single overhead cam shaft has eight pairs of cams, which are shown in detail at *B*. For each valve there is a three-armed rocker, one arm of which is connected to the stem of the valve and the two others are in contact respectively with the opening and closing cams. The connection to the end of the valve stem is made by a short connecting link which is screwed on to the end of the valve stem and locked in position. This allows some adjustment to be made between the valves and the actuating rocker. It will be evident that one cam and one rocker arm produces the opening of the valve and that the corresponding rocker arm and cam result in the closing of the valve. If the opening cam has the usual convex profile the closing cam has a correspondingly concave profile. It will be noticed that a light valve spring is shown in drawing. This is provided to give a final seating to its valve after it has been closed by the cam. This is not absolutely necessary, as an engine has been run successfully without these springs. The whole mechanism is contained within an overhead aluminum cover.

The positive valve system used on the De Lage motor is shown at *D*. In this the valves are actuated as shown in sectional views *D* and *E*. The valve system is unique in that four valves are provided per cylinder, two for exhaust and two for intake. The valves are mounted side by side, as shown at *E*, so the double actuator member may be operated by a single set of cams. The valve operating member consists of a yoke having guide bars at the top and bottom. The actuating cam works inside of this yoke. The usual form of cam acts on the lower portion of the yoke to open the valve, while the concave cam acts on the upper part to close the valves. In this design provision is made for expansion of the valve stems due to heat, and these are not positively connected to the actuating member. As shown at *E*, the valves are held against the seat by short coil springs at the upper end of the stem. These are very stiff and are only intended to provide for expansion. A slight space is left between the top of the valve

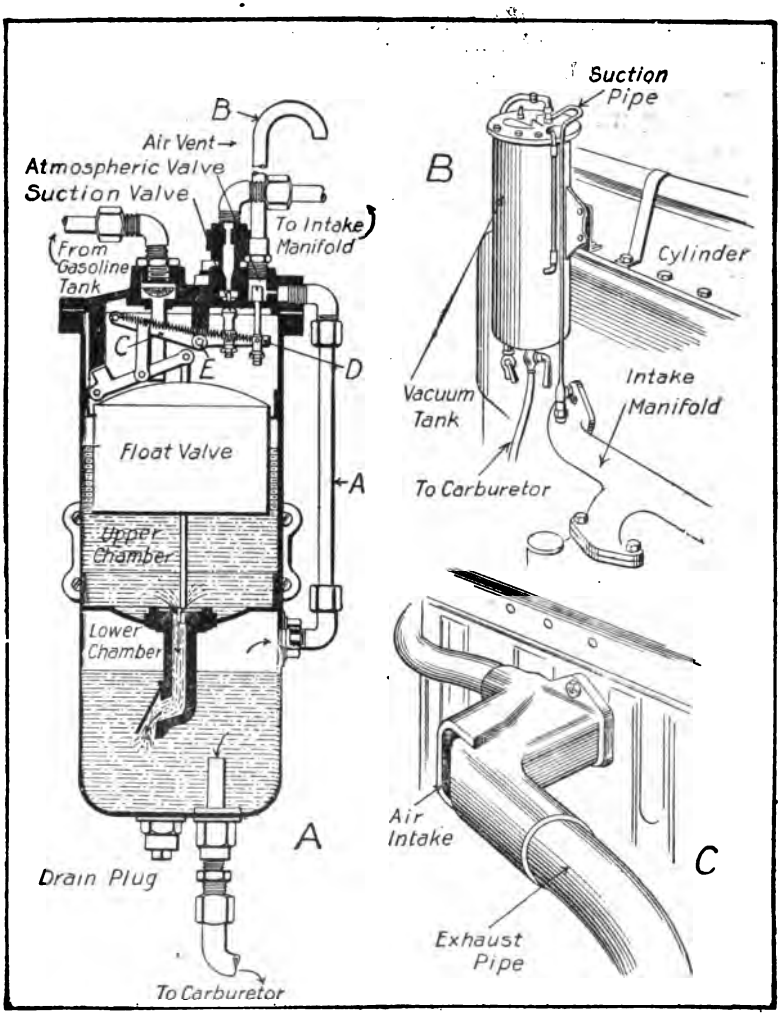


Fig. 338.—The Stewart Vacuum Fuel Feed and One Method of Application.

stem and the portion of the operating member that bears against them when the regular profile cam exerts its pressure on the bottom of the valve operating mechanism. Another novelty in this

motor design is that the cam shafts and the valve operating members are carried in casings attached above the motor by housing supports in the form of small steel pillars. The overhead cam shafts are operated by means of bevel gearing.

Q. What is the Stewart vacuum fuel feed?

A. One of the marked tendencies has been the adoption of a vacuum fuel feed system to draw the gasoline from tanks placed lower than the carburetor instead of using either exhaust gas or air pressure to achieve this end. The device generally fitted is the Stewart vacuum feed tank which is clearly shown in section at Fig. 338-A, and method of application to the side of a motor at Fig. 338-B. In this system the suction of a motor is employed to draw gasoline from the main fuel tank to the auxiliary tank incorporated in the device and from this tank the liquid flows to the carburetor. It is claimed that all the advantages of the pressure system are obtained with very little more complication than is found on the ordinary gravity feed. The mechanism is all contained in the cylindrical tank shown, which may be mounted either on the front of the dash or on the side of the engine as shown at Fig. 338-B.

The tank is divided into two chambers, the upper one being the filling chamber and the lower one the emptying chamber. The former, which is at the top of the device, contains the float valve, as well as the pipes running to the main fuel container and to the intake manifold. The lower chamber is used to supply the carburetor with gasoline and is under atmospheric pressure at all times, so the flow of fuel from it is by means of gravity only. Since this chamber is located somewhat above the carburetor, there must always be free flow of fuel. Atmospheric pressure is maintained by the pipes *A* and *B,* the latter opening into the air. In order that the fuel will be sucked from a main tank to the upper chamber, the suction valve must be opened and the atmospheric valve closed. Under these conditions the float is at the bottom and the suction at the intake manifold produces a vacuum in the tank which draws the gasoline from the main tank to the upper chamber. When the upper chamber is filled at the proper

height the float rises to the top, this closing the suction valve and opening the atmospheric valve. As the suction is now cut off, the lower chamber is filled by gravity owing to there being atmospheric pressure in both upper and lower chambers. A flap valve is provided between the two chambers to prevent the gasoline in the lower one from being sucked back into the upper one. The atmospheric and suction valves are controlled by the levers *C* and *D*, both of which are pivoted at *E*, their outer ends being connected by two coil springs. It is seen that the arrangement of these two springs is such that the float must be held at the extremity of its movement, and that it cannot assume an intermediate position.

This intermediate action is required to insure that the upper part of the tank may be under atmospheric pressure part of the time for the gasoline to flow to the lower chamber. When the level of gasoline drops to a certain point, the float falls, this opening the suction valve and closing the atmospheric valve. The suction of the motor then causes a flow of fuel from the main container. As soon as the level rises to the proper height the float returns to its upper position. It takes about two seconds for the chamber to become full enough to raise the float, as but .05 gallon is transferred at a time. The pipe running from the bottom of the lower chamber to the carburetor extends up a way, so that there is but little chance of dirt or water being carried to the float chamber.

If the car is allowed to stand long enough so that the tank becomes empty, it will be replenished after the motor has been cranked over four or five times with the throttle closed. The installation of the Stewart Vacuum-Gravity System is very simple. The suction pipe tapped into the manifold at a point as near the cylinders as possible, while the fuel pipe is inserted into the gasoline tank and runs to the bottom of that member. There is a screen at the end of the fuel pipe to prevent any trouble due to deposits of sediment in the main container. As the fuel is sucked from the gasoline tank a small vent must be made in the tank filler cap so that the pressure in the main tank will always be that of the atmosphere.

Q. What is an "air stove" and how is it used?

A. In this illustration (Fig. 338) is also shown another recent improvement in carburetion at *C*. Owing to the lower grades of fuel now being generally supplied, the primary inlet of the carburetor is connected to an air stove fastened to the exhaust pipe in order that heated air will be supplied the mixture. This assists in vaporization. The fitting outlined is exceptionally neat, inasmuch as it is a casting with which is incorporated the discharge elbow from the exhaust valve chambers of the motor to which the exhaust pipe leading to the muffler is secured.

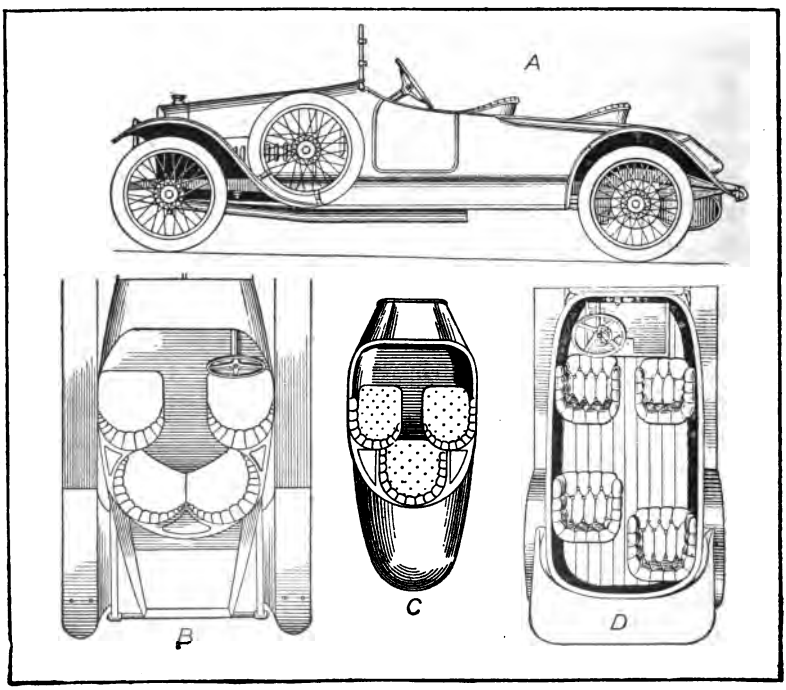


Fig. 341.—Recent Developments in Automobile Body Design.

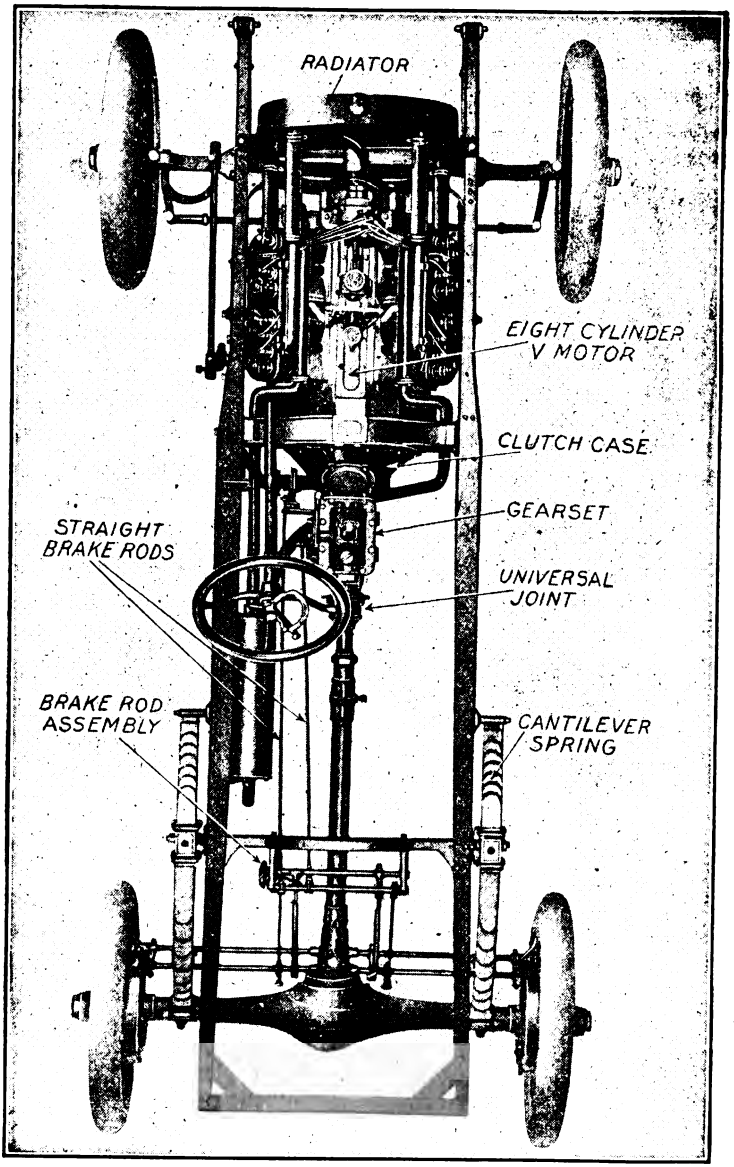


Fig. 342.—Plan View of King Eight Cylinder Automobile Chassis Shows Late Trend in Automobile Design. Note Cantilever Springs.

Q. Have any changes been made in body design?

A. The pronounced tendency in body design is to carry out the stream line effect so that there are no sharp angles anywhere on the body. The hood meets the body, which is provided with a cowl dash. An example of an extreme "boat type" body is shown at Fig. 341-A. Seating arrangements have been changed to some extent. At *B* a "cluster" system of arranging the seats for carrying four passengers in a body but little larger than that usually provided on a two passenger car is shown. The advantage of this arrangement is that it brings all passengers near the center of the body and between the springs, which makes for easy riding. A clover leaf seating arrangement for three passengers is shown at *C*. In the body outlined at *D* the seats are in the form of movable arm chairs which may be placed as desired, and securely locked after they are located to suit the convenience of the occupants.

Q. What are the tendencies noted in modern chassis design?

A. An example of a modern chassis in which an eight cylinder V type engine is used is shown at Fig. 342. This shows clearly the combination of change speed gear set and clutch case with the engine crank case to form the unit power plant and also outlines the application of cantilever springs, which are used on many of the 1916 cars. The tendency toward the use of straight brake rods all carried inside of the chassis frame is also clearly outlined. The practical application of a cantilever spring is shown at Fig. 343-A. This type of spring is said to be easier riding than any form heretofore developed and was first used on automobiles by F. W. Lanchester, of England, who has favored this type for years. With a cantilever spring there is less unsprung weight on the rear axle than with the usual type, as it is apparent that only those portions of a spring which move up and down through the same range as the body are fully spring supported. The parts fastened to the axle are wholly unsprung and intermediate portions are only partially spring supported. Another advantage of the cantilever spring is that for a given length of body and frame it permits a longer wheel base or provides the same effect. The way

the spring is attached to the frame side members permits of increasing the wheel base eight or ten inches over that possible with a conventional semi-elliptic or three-quarter elliptic spring unless these have a large overhang at the rear of the vehicle. If a certain

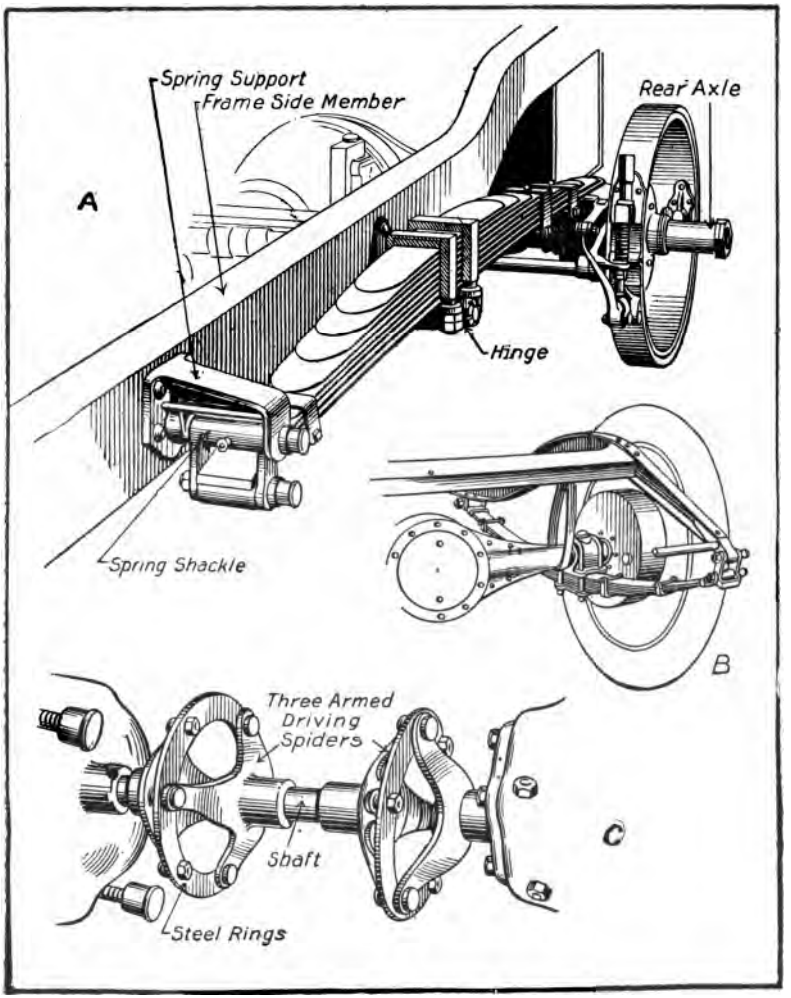


Fig. 343.—New Methods of Springing at A and B and Steel Plate Universal at C.

car is equipped with semi-elliptic springs and these are changed over so the mounting is as a cantilever spring, one would find that they deflect more than before, and that they are also more susceptible to minute road irregularities than they were when hung up in the conventional manner.

Q. How is the cantilever spring usually installed?

A. The usual method of hanging a cantilever spring is shown at *A*. The thickest portion of the spring is attached to a fitting, which rocks on a hanger pin secured on the frame side. The front end of the spring is shackled to the spring support in the usual manner, while the rear end is attached to the rear axle. Another tendency is to use the underslung semi-elliptic or three-quarter elliptic springs, as shown at Fig. 343-B. This makes it possible to carry the weight lower than is the case when the spring is placed on the top of the axle, and it also permits a greater range of spring movement without cambering the frame side member unduly.

Q. What is the leather universal joint construction?

A. A number of cars now use spring plate or leather disc universal joints at points where these are not subjected to undue deflection in place of the sliding jaw coupling or Oldham couplings so widely used heretofore. A point where they could be used to special advantage is between the clutch and gear case, and for magneto or starting generator drive. Some have been applied on the end of a propeller drive shaft, where the degree of movement was not apt to be excessive owing to the use of straight line drive. The construction of these joints is clearly shown at Fig. 343-C. Two three arm driving spiders are attached to a flexible steel ring, or to a series of leather rings, as shown in the illustration, the degree of flexibility of the ring member being such as to permit slight disalignment, and at the same time secure positive driving. The advantage of this form of joint is that it is quiet in action and that there is nothing to wear out.

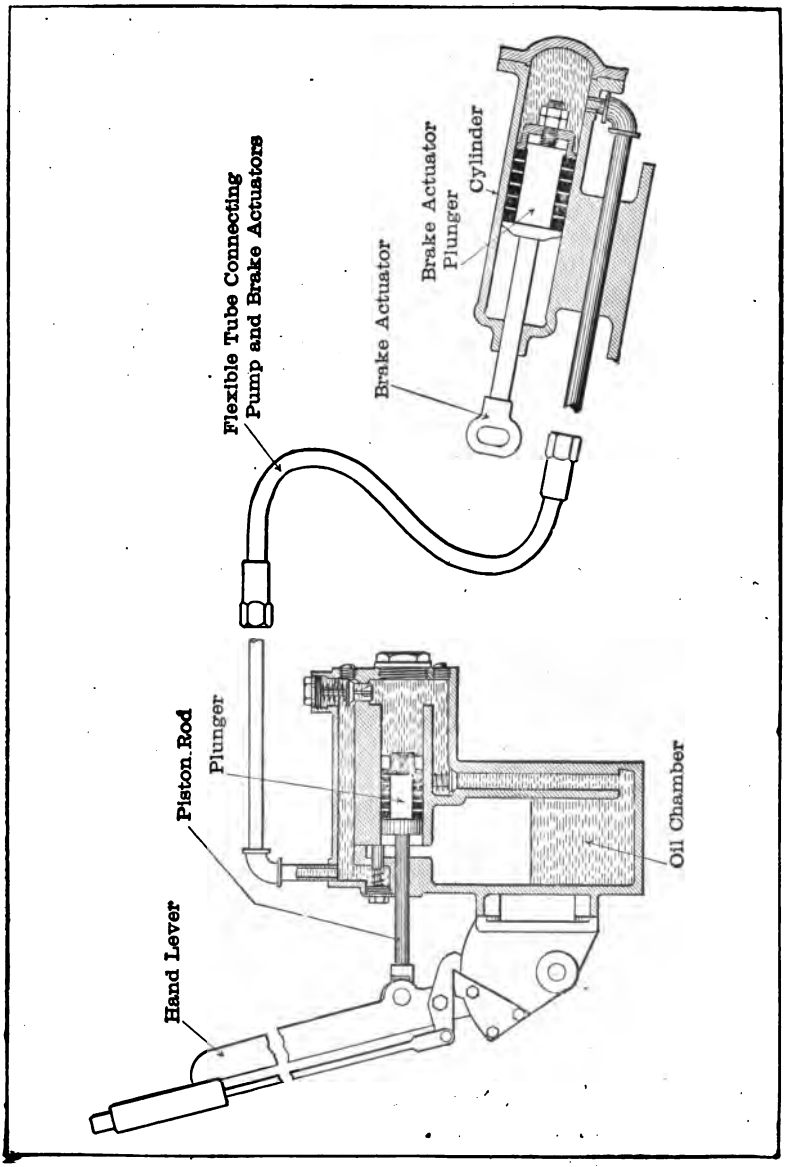


Fig. 344.—Method of Operating Rear Hub Brakes Hydraulically Used on Knox Tractor.

Q. What is a hydraulic brake?

A. A novel method of actuating the rear wheel brakes on the 1915 Knox tractor is shown at Fig. 344. Instead of the usual mechanical leverage the brakes are applied by hydraulic pressure. The hand lever works a pump plunger which forces oil into the cylinder of a brake actuating member carried on the radius rods. When the applying lever is worked back and forth, it acts as a pump-handle, and forces liquid into the braking cylinder. By having a difference in size between the pump plunger and that

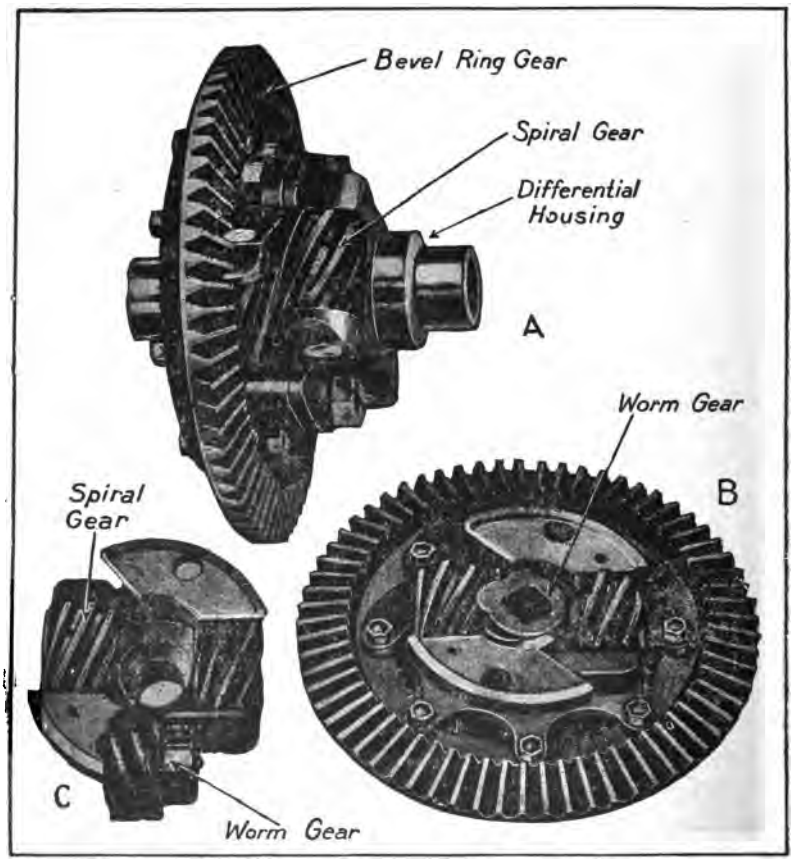


Fig. 345.—Assembled View of the Walter Positive Drive Differential at A.—View of Ring Gear, Differential Parts and Worm Gearing.

actuating the brake a great increase in power is obtained and the brakes may be applied with very little exertion. When it is desired to release the brakes, the lever is thrown way forward, which opens a bypass valve which allows the oil to flow back into the container, relieving the pressure against the brake actuating plunger. This is then drawn back by the brake release spring and forces the liquid out of the braking cylinder. The brakes are of the usual friction band form.

Q. What is the positive drive differential?

A. A new type of worm differential which is of exceedingly simple design, and which has the meritorious feature of driving both wheels, regardless of the traction condition of either, has been put on the market under the name of the Walter positive drive differential. The differential consists of two pairs of spiral gears mounted in a two-part housing as shown in the accompanying illustration. The two pairs of spiral gears mesh together and also mesh with worms mounted in the housing and on the drive-shaft. The housing is in halves which are alike except for the flange for the bevel gear. The two bolts which hold the housing together set one ahead of the other in order to bring the spiral gear pairs into direct mesh.

The worm can be given any desired pitch within the limits of good practice, but in the standard design they will have a 22.5 degree lead angle, as this has been found to be the best in practice. The construction is not limited, however, to any special spiral angle. With this construction, the operation will be as follows: The driving resistances of the wheel tend to rotate the spiral gears on their pins in opposite directions. When one wheel has a greater resistance the inequality of force cannot drive the other wheel faster, as the spiral gear cannot drive the worm on account of the relationship of the pitch angle to one another. The result is that both wheels are positively driven. When turning, the outside wheel rolls faster and so permits the inside wheel to turn correspondingly slower, giving a compensating differential action.

Worm gearing has been chosen because it provides strength, while at the same time giving a smooth and pliant action. The flexibility of the worm gearing is very effective in diminishing the shocks transmitted through the differential mechanism. Five advantages are claimed for this type of differential. These may be briefly summarized as follows: 1—The car will not stall if a single wheel alone has traction. 2—The motor power is used more effectively, as both wheels are steadily driven. 3—Skidding is eliminated in many cases, due to the steady driving of both wheels. 4—More even pulling is secured on a rough road for the same reason. 5—The wear and strain on tires due to an accelerated or spinning wheel recovering the road is eliminated, a notable advantage for economy.

Q. What is the Entz electric transmission?

A. This system was first devised eight or nine years ago, and has been recently reintroduced in an improved and simplified form. The appearance of the unit is clearly shown at Fig. 346. Bolted to the rear of the engine crank shaft is an aluminum housing, which carries the electrical system. Two arms of this crank case rest on the chassis frame to support it. Inside of the housing is another case bolted to a flange at the rear end of the crank shaft. This is the frame of the forward unit of transmission, which carries the field coils, and which acts as a flywheel for the engine. To the rear end of the stationary outside housing the field frame of the rear electrical unit, which is intended to be stationary, is attached. The armatures of both units are attached to the same shaft.

Under conditions of light running, when the high gear or direct drive would be used in a car equipped with a sliding gear transmission, the armature of the Entz system is short circuited, but the slippage and loss then amounts to only a few per cent.

When the resistance to car movement is greater, so that a lower gear must be employed, in the gear driven cars, with the Entz system, the current produced in the first armature by the slip is sent to the windings of the motor where it produces useful mechanical power. As the armature of the motor is secured to the propeller

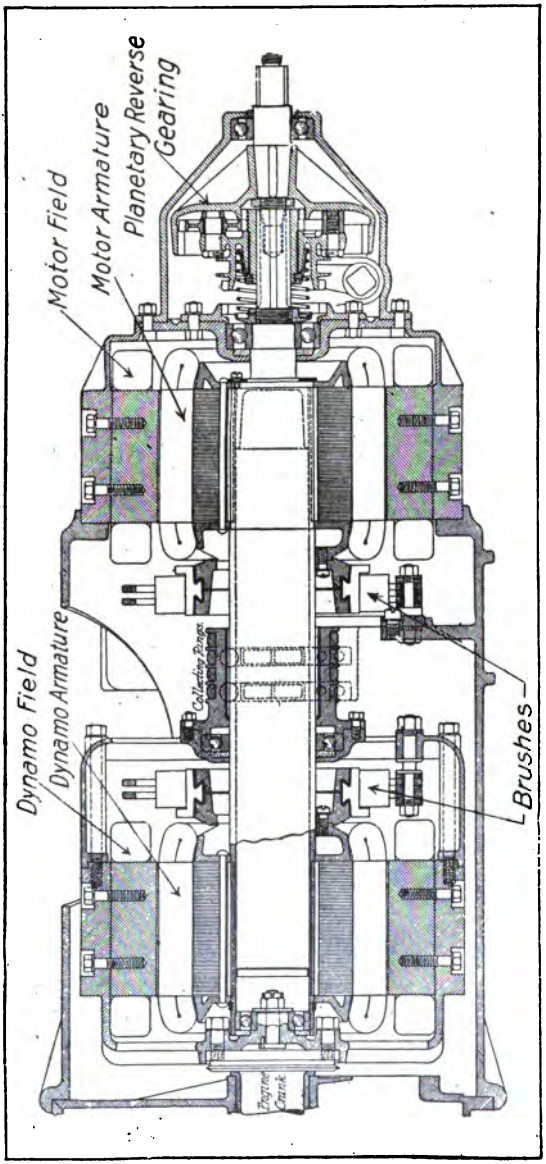


Fig. 346.—Modern Adaptation of the Entz Electric Transmission on the Owen Electric Magnetic Car.

shaft it transforms the electrical energy produced by the slip at the generator to mechanical power, which supplements that transmitted by the generator armature. The windings of the second machine are such that the electric system can increase the torque or turning effort of the engine three times, at the same time reducing the speed of driving pinion rotation at the rear axle to one-third that of the engine speed. The engine is permitted to develop its full power, and to turn at such speed as is necessary to secure this effect, and when the resistance to road wheel rotation is such that these must turn slower, instead of slowing up the engine speed it may be kept at the same point and the armature of the generator allowed to slip and generate current, which is then directed to the second machine.

Q. What are the latest 1916 engine developments?

A. It is not only in multiplying the number of cylinders or arranging them in V form to obtain compactness that the automobile power plant of 1916 has been improved. The speeds of crankshaft rotation are higher than ever before, and many touring car motors run at higher speeds than the racing car power plants of a few years ago. More power is therefore obtained for a given piston displacement than formerly; this being made possible by an increase in valve sizes, changes in compression ratios and the adoption of automatic pressure feed lubricating systems that insure the thorough lubrication of every internal motor part. The great increase in crankshaft speed has been made possible by better balancing and the lightening of reciprocating parts by using lighter pistons of aluminum alloy. These are fully described herewith.

Q. Outline use of aluminum in motor parts.

A. Aluminum pistons outlined at Fig. 347, *C, D, E* and *F*, have replaced cast iron members in many motors, as these weigh about one-third as much as the cast iron forms of the same size, while the reduction in the inertia forces has made it possible to increase the engine speed without correspondingly stressing the connecting rods, crankshaft and engine bearings.

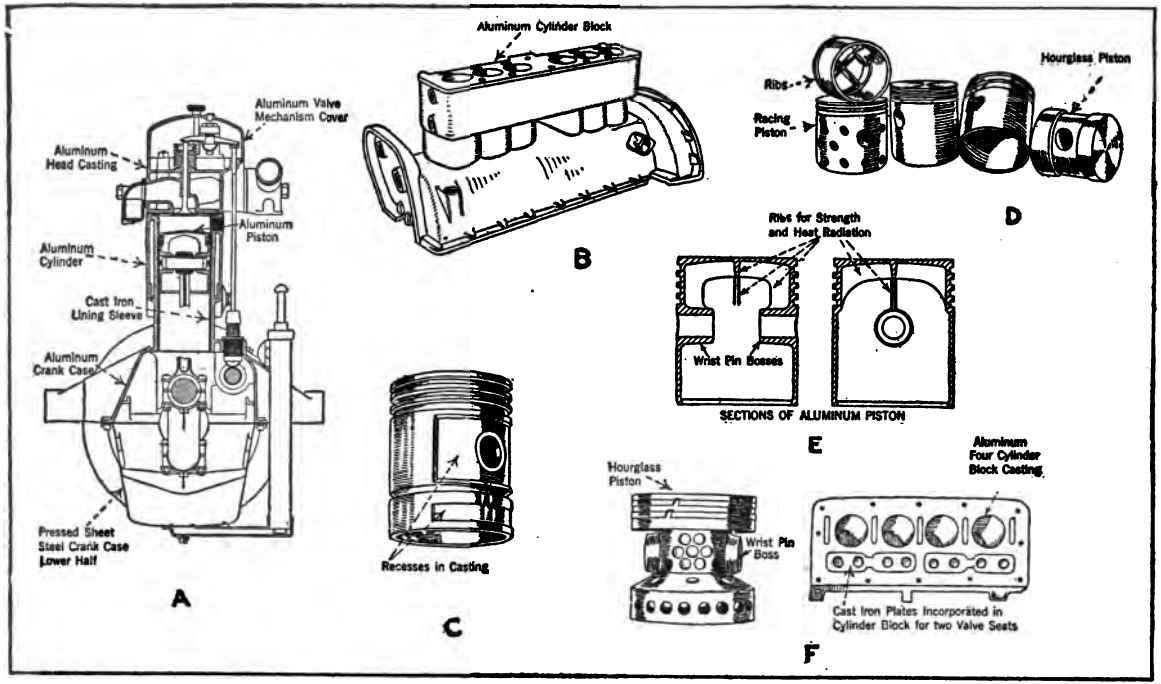


Fig. 347.—Aluminnm will be used for more Automobile Engine Parts during 1916. The sectional view of the overhead valve motor at A shows the use of aluminum cylinder block and cylinder head casting. A six-cylinder aluminum block casting is shown at B, while various interesting forms of aluminum pistons are shown at C, D, E and F. Top view of a four-cylinder aluminum block casting showing the use of iron plates for valve seats is depicted at the lower righthand corner.

Aluminum has not only been used for pistons, but a number of motors will be built for the coming season that will use aluminum cylinder block castings as well as shown at Fig. 347-B. Of course, the aluminum alloy is too soft to be used as a bearing for the piston, and it will not withstand the hammering action of the valve. This makes the use of cast iron imperative in all motors. When used in connection with an aluminum cylinder block the cast iron pieces are placed in the mould so that they act as cylinder liners and valve seats, and the molten metal is poured around them when the cylinder is cast. It is said that this construction results in an intimate bond between the cast iron and the surrounding aluminum metal. Aluminum has for a number of years been used in many motor car parts. Alloys have been developed that have greater strength than cast iron and that are not so brittle. Its use for manifolds, clutch cones and engine crank and gear cases has been general for a number of years.

At first thought it would seem as though aluminum would be entirely unsuited for use in those portions of internal combustion engines exposed to the heat of the explosion, on account of the low melting point of that metal and its disadvantageous quality of suddenly "wilting" when a critical point in the temperature is reached. Those who hesitated to use aluminum on account of this defect lost sight of the great heat conductivity of that metal, which is considerably more than that of cast iron. It was found in early experiments with aluminum pistons that this quality of quick radiation meant that aluminum pistons remained considerably cooler than cast iron ones in service, which was attested to by the reduced formation of carbon deposits thereon. The use of aluminum makes possible a marked reduction in power plant weight. A small four cylinder engine which was not particularly heavy even with cast iron cylinders was found to weigh 100 pounds less when the cylinder block, pistons, and upper half of the crank case had been made of aluminum instead of cast iron.

Q. Explain latest types of battery ignition.

A. Because of the almost universal employment of electricity for lighting and starting systems, the battery ignition system has been improved materially inasmuch as the storage battery supplying the current is constantly charged by a generator. A number of systems has been devised, these operating on two different principles, the open and the closed circuit.

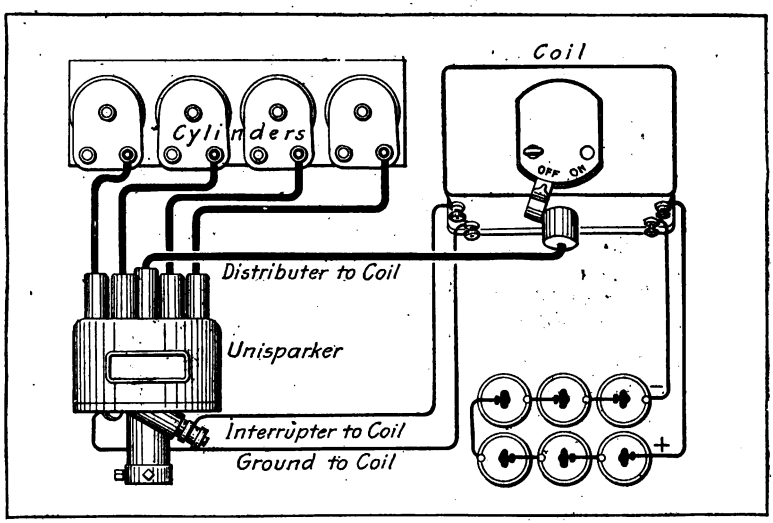


Fig. 348.—Atwater-Kent Uni-Sparker System.

One of the best known of the short contact forms of timer is the Atwater-Kent, which is usually combined with a secondary distributor as shown at Fig. 349. The method of placing this timing and distributing member in circuit is clearly shown in wiring diagram Fig. 348. The advantage of a timer of the form shown, as contrasted to the simple type previously considered, is that a one unit induction coil will serve any number of cylinders from 2 to 8, whereas with the roller type a separate induction coil is needed for each cylinder to be fired. It will be observed that the coile used with the Atwater-Kent system has five terminals, four of these being primary terminals, one at the center of the coil box

a secondary or high tension terminal. A set of six dry cells connected in series is wired to one side of the coil box as indicated. One of the two remaining primary terminals runs to the primary contact at the bottom of the interrupter, the other to a grounding screw attached to the interrupter casing. The secondary terminal is connected to the central terminal of the distributor, while the remaining four terminals are joined to the plugs in the engine

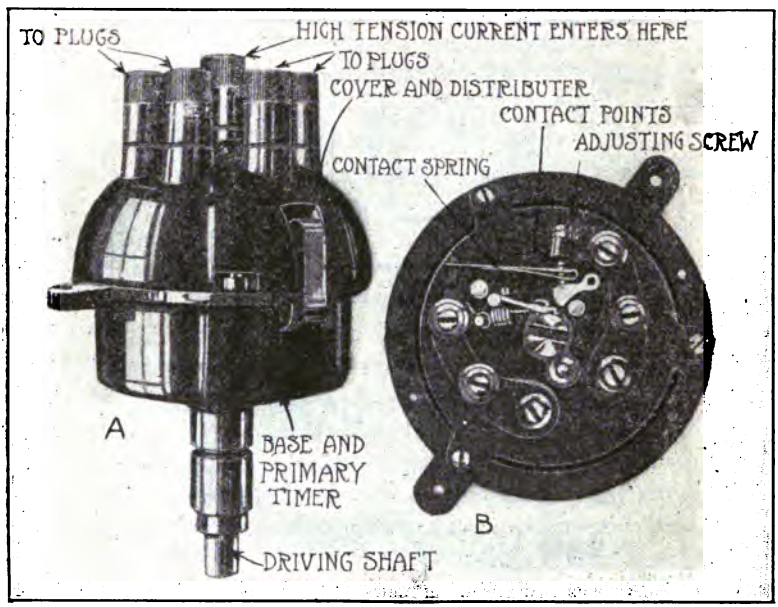


Fig. 349.—Showing Construction of Atwater-Kent Uni-Sparker.

cylinders in such order as to insure proper sequence of explosions. The external view of the Atwater-Kent uni-sparker is shown at Fig. 349, *A*. In this a centrifugal mechanism is contained in the lower part of the casing by which the spark is automatically advanced as the speed of the engine increases.

The only points that will wear on a device of this character are the contact points which are clearly shown in the view of the contact breaker mechanism at *B*. The revolving shaft in the center

has a number of notches, two, three, four, six, or eight, according to the number of cylinders to be fired, cut into it. A light, hardened steel trigger, *B*, is held against the shaft at this point by a small spring. On turning the shaft this trigger is carried forward by the notches in the shaft, and is suddenly released as the hook end leaves the notch. In so doing the back of the trigger strikes a small pivoted hammer, *D*, situated between the trigger and the spring carrying the contact points. This causes the contact points, *K*, to open and close with remarkable rapidity, but one contact being made for each spark. When it is desired to adjust the platinum contact points, as when they show signs of wear, it is only necessary to remove one or more of a number of extremely thin washers under the head of the adjustment screw and to replace the screw. The contact point should be absolutely clean and bright and have smooth contacting surfaces. The distributor portion of the device consists of a hard rubber block fitted to the top of the primary shaft, this carrying a brass quadrant that passes the high tension current to the spark plugs by means of the terminal points imbedded in the hemispherical cover. There is no actual contact between the rotating quadrant and the distributor points, as the high tension current is capable of jumping the very slight gap that exists between them. Owing to there being no actual contact, there will be no depreciation in the distributor or upper portion. The center terminal, which is in connection with the induction coil, is a combination of carbon and brass, and a light, flat spring on the quadrant bears against it to maintain positive electrical connection. The distributor cover is easily removed without the use of tools, as it is held by spring clips. Location or dowel pins in its lower edge insure that it will be replaced in the correct position.

Q. What is the "closed circuit" system?

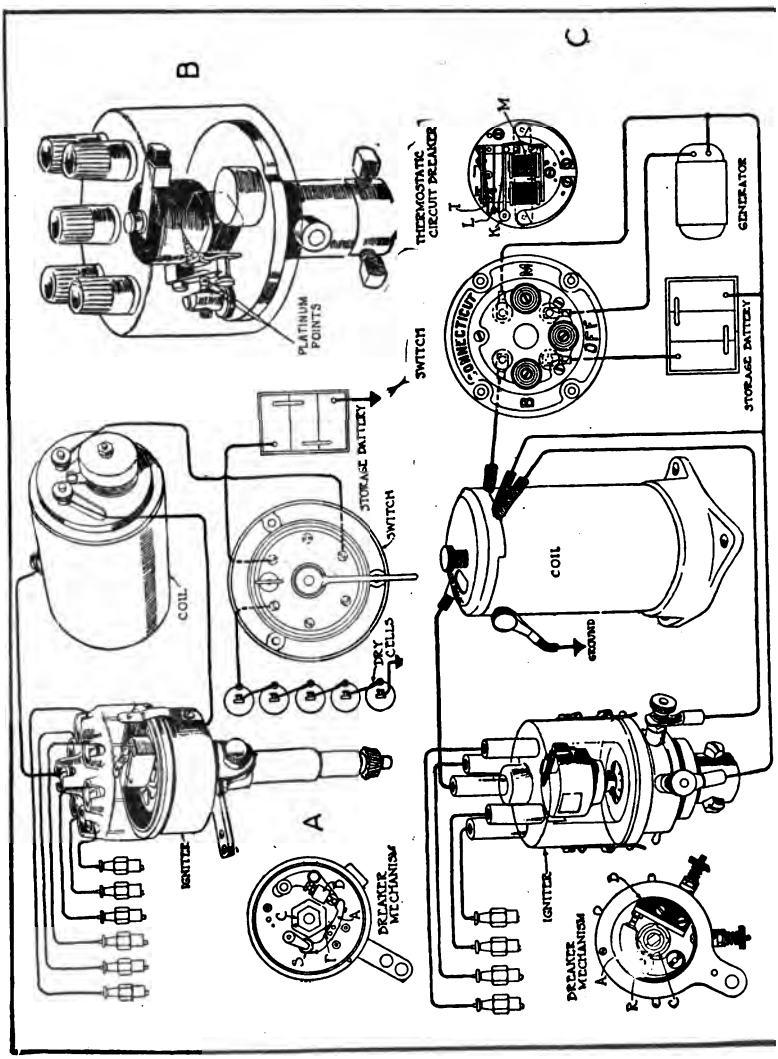
A. An example of the closed circuit system is shown at *C*, Fig. 350, and is of Connecticut design, the complete ignition system consisting of a combined timer and high tension distributor, a separate induction coil and a switch. The system is distinctive in that the timer is so constructed that the primary circuit of the coil is permitted to become thoroughly saturated with electricity

before the points separate, with a result that a spark of maximum intensity is produced. The action is very much the same as that of a magneto on account of the saturation of the winding. Another feature is the incorporation with the switch of a thermostatically operated electro-magnetic device which automatically breaks the connection between the battery and coil should the switch be left on with the motor idle.

The contact breaker mechanism consists of an arm *A* carrying one contact, a stationary block *B* carrying the other contact, a fiber roller *R* which is carried by the arm *A* and operated by points on the cam *C*, which is mounted on the driving shaft. Normally the contacts are held together under the action of a light spring. As the four cams, which in touching the roller *R* raise the arm and separate the contacts, are 90 degrees for a four-cylinder motor, the period of saturation of the coil or the length of time the current flows through it to the battery is sufficiently long so that when the points have separated the current which has "piled" up induces an intensely hot spark at the plugs. This is an advantage inasmuch as it insures prompt starting and regular ignition at low engine speed as well as providing positive ignition at high engine speed.

The thermostatic circuit breaking mechanism is very simple. This consists of the thermostat *T*, which heats when the current passes through it for from thirty seconds to four minutes without interruption, and thus is bent downward, making contact with the contact *L*. This completes an electrical circuit which energizes the magnets *M*, causing the arm *K* to operate like the clapper in an electric bell. This arm strikes against the plate, which releases whichever of the two buttons in the switch may be depressed.

As will be observed, the transformer coil provided has five terminals. One of these is directly connected with the ground, the other leads to the central secondary distributing brush of the timer-distributor. Of the three primary leads, one goes to the switch, one to the wire leading from the storage battery to the timer, and one directly to a terminal on the timer. The switch is provided with three buttons, the one marked *B* being depressed to start the engine, as the ignition current is then drawn from the storage bat-


B
PLATINUM POINTS
THERMOSTATIC CIRCUIT BREAKER
C
CONNECTICUT
OFF
STORAGE BATTERY
SWITCH
GENERATOR
COIL
IGNITER
DRY CELLS
GROUND
A
BREAKER MECHANISM

tery. After the engine has been started the button marked *M* is pressed in, this taking the current directly from the generator. To interrupt ignition the button "off" is pressed in, this releasing whichever of the buttons, *B* or *M*, is depressed. Four wires run from the distributor section of the igniter to the spark plug.

Q. Describe Remy ignition system.

A. The Remy system also operates on the closed circuit principle and is shown at *A*, Fig. 350, in a form adapted for six-cylinder engine ignition. The transformer coil is of the three terminal type, one secondary going to the central secondary distributing brush of the timer while one primary is joined to the primary contact terminal of the timer portion of the igniter. The remaining coil terminal is joined to the switch. One of the poles of the storage battery and one of the series connected dry cell batteries are grounded, while from the other two the wires run to the switch contacts. The current may thus be derived either from the dry cell batteries for emergency or from the storage battery for regular ignition purposes. The construction of the timer which incorporates the breaker mechanism is clearly shown. The movable platinum contact point is carried by the arm *A*, which fulcrums on the bearing *S*, and which has a piece of hard steel *F* riveted to it to act as a cam rider. The cam *C* is of hexagonal form, having six points which separate the contacts when they ride over the shoe *F* attached to the arm *A*. The fixed platinum contact point *B* is so arranged that it may be adjusted by moving in or out as conditions demand. It is to the member that the primary terminal of the coil is connected.

Q. Describe typical timer distributor.

A. A typical combined timer distributor known as the Halladay is shown at *B*, Fig. 350. The make and break mechanism is very simple in design, as is the distributing mechanism. The contact between the platinum points is established by a four point cam. The secondary current is distributed from the central terminal to the four distributing terminals by a carbon brush very much similar in design to that employed in a high tension magneto. This operates on the open circuit principle.

LESSON THIRTY-EIGHT

ELECTRIC STARTING SYSTEMS

Q. Name principal types of motor starters, and give advantages of most popular system.

A. Automatic motor starters may be of three general types, mechanical starters, which include various leverage, spring and gearing combinations that replace the starting crank, air starters, in which compressed air is admitted to the motor cylinders from a tank where it is stored under pressure, and electric starters where a small motor is employed to rotate the crank shaft by some direct mechanical connection. The electric starter is the most popular type because on most cars electric lighting systems may be operated from the same battery and dynamo that supplies current for the starting motor. The electric starter is an easily operated form and can be proportioned so that it will turn an engine over positively. In fact, some electric starters are powerful enough to actually propel the car a short distance.

The disadvantage of the mechanical starters, which comprise the various spring and lever type, is that they depend to a certain extent on human power. The spring of a spring starter is capable of giving the motor eight or ten brisk turns before the spring will be unwound and provision is made for automatically rewinding the spring by the motor power as soon as the engine starts. If the engine fails to start, owing to some defect in carburetion or ignition, and the spring becomes unwound, it is necessary for the operator to rewind the springs by means of a small crank provided for that purpose, a somewhat tedious proceeding. The usual form of mechanical starter requires almost as much energy to start the motor as is needed at the starting crank of the ordinary pattern, the only advantage being in most cases the power plant may be put in motion from the seat.

An air starter system has a disadvantage in that the air is apt to cool the cylinders and prevent proper starting on account of condensing the gas and also preventing the cylinder from taking in a charge of good rich gas, as it does when cranked by external means. It is evident that the air supplied the cylinders must dilute the entering charge of gas to some extent as well as prevent the motor from taking in the proper charges. Several air starters have been designed that have given good results in practice, however.

Q. Describe typical air starter system.

A. A typical air starter system is shown at Fig. 351. The air is supplied by a four cylinder air pressure pump which directs it to a storage tank, through a suitable return check valve. A pipe leading from the storage tank goes to a distributor fitting, driven by the motor, which directs an air current only to the cylinder which is at the firing point when the main operating valves are opened. The air is directed against the top of the piston and as it has a pressure of 150 or 160 pounds per square inch it will give a series of initial impulses to the pistons and turn over the crank shaft until the charge of gas drawn into one of the cylinders while the shaft is rotating explodes and permits the engine to take up its cycle of operation. The system shown was used on early Chalmers cars and a similar system was incorporated in the Winton automobile as well. An advantage of the air starting system is that one always has a supply of fresh cool air under pressure to blow up tires with. A simple valve is included in the pipe line so a rubber hose may be run from the dash to any one of the tires needing inflation.

Q. How do mechanical starters work and describe some typical forms.

A. While different makes of cars have been marketed using air starting systems, there has been no car offered with a mechanical starter, so wherever these are used they have been applied by the owner of the vehicle and not the manufacturer. Owing to the wide distribution of the Ford automobile, and the fact that the

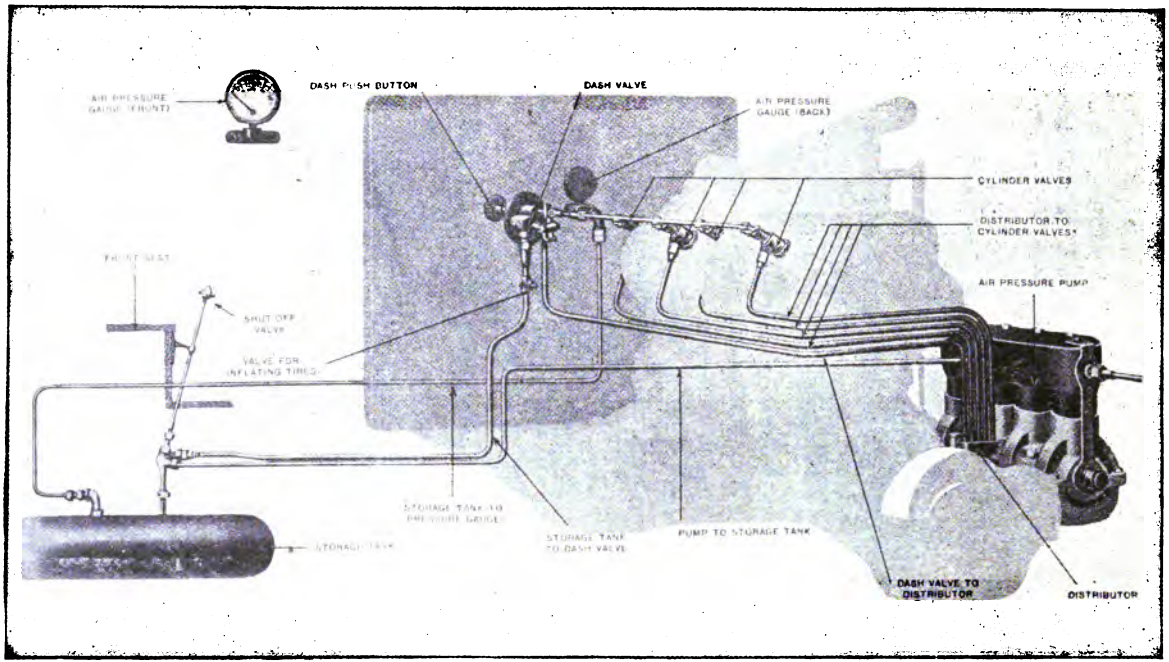


Fig. 351.—Arrangement of Important Components and Piping of the Chalmers Air Starting System.

makers make no provision for a self-starting motor, various forms of simple starters by which the motor may be cranked from the seat have been offered. Two of these are shown at the top of Fig. 352. That at *A* consists of a rachet clutch which is attached to the starting end of the crankshaft and which is operated by means of chain connection with the smaller pulley of a two diameter pulley wheel. The larger wheel carries a wire cable which is attached to a straight rod running through the dash board and terminating in a handle convenient to the driver's hand. A pull on the spade type handle provided at the end of the rod will move the pulley wheel and produce a corresponding movement of the starting rachet which turns the engine crankshaft over in the same way as the hand crank does. A modification of the device shown at *A* is outlined at *B*. This works on the same principle, except that an odd-shaped member is used to turn over the engine crankshaft. These devices are in no sense of the word "self-starters," but on light motor cars they provide an effective substitute in that the engine may be turned over without undue exertion and without leaving the seat. This is an advantage of some moment when the engine stalls in traffic, or under conditions where it would be inconvenient to get out of the car.

Q. Do all mechanical starters attach to the front of the engine crankshaft?

A. Two types of mechanical starters known as the Wilkinson are shown at the bottom of the illustration, Fig. 352. The one at *D* is operated by pulling a handle on the dash, the one at *C* by a pedal designed for foot actuation. The mechanism is such that the flywheel is pushed around by a lever which will engage with either a stud or a shoulder on the flywheel. The type at the left uses the studded flywheel, there being four of these marked "S." When the arm *C* is moved by depressing a pedal, the finger *A* contacts with one of the stubs and turns the flywheel. Return engagement is produced by the large spring shown. In order to minimize liability of injury from backfire, the Wilkinson device is constructed so that the pawl *D* rises on the cam which bears against the collar *E*, and thus throws the finger out of engage-

ment with the stud. One thrust of the pedal will turn the flywheel of a four-cylinder engine sufficiently to cause one cylinder to fire should ignition and carburetion systems be functioning properly. The type at *D* is just as simple, but is

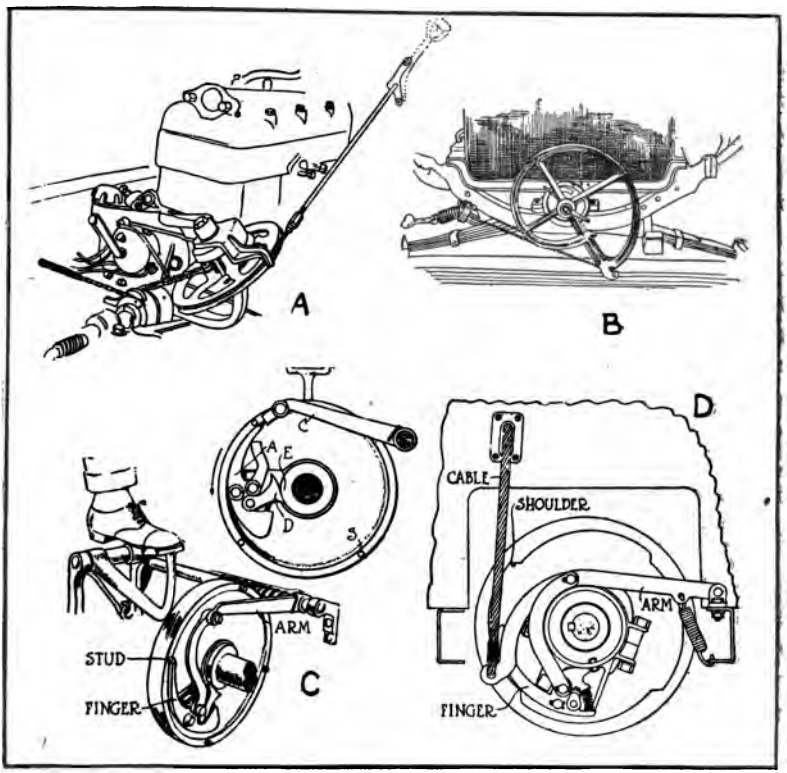


Fig. 352.—Showing Construction of Mechanical Devices for Starting Gasoline Engine from the Operator's Seat.

modified somewhat in its construction. In this a hand lever is used to rotate the flywheel, and instead of using studs on the flywheel rim, four shoulders in the interior periphery do the work. These shoulders may be cast with the wheel, or in some cars it is possible to have them cut in the flywheel. The operation is the same as that of the type previously described as the movement of

the cable causes the finger to engage with one of the shoulders, and thus turn the flywheel.

Q. How do electric starters work and how are they classified?

A. Electric lighting, cranking and ignition systems for motor cars are of such recent development that it is not possible to describe all systems used for this purpose. Not only do the individual systems vary in detail, but the components of the same system are often of different construction when used on cars of different makes. The standard equipment must include three important functions, namely, the generator which is driven by the engine end which produces electric current to keep a storage battery charged, and the starting motor which is in mechanical connection with the engine and in electrical connection with the storage battery when it is desired to turn the engine over for starting. If the motor and generator are combined in one instrument the starting system is known as a one unit type. If the motor is one appliance and the generator another, the system is said to be a two unit system. Each of these has advantages, and both forms have demonstrated that they are thoroughly practical.

Q. Name other parts of electric starting system.

A. In addition to the three main items enumerated, various accessories, such as switches, ammeters, connectors, wiring, protective circuit breakers, automatic current regulators, etc., are necessary for the convenient distribution and control of the electric current.

Q. Describe arrangement of parts of "one unit" system.

A. The elements of a one unit system are shown in diagram form at the bottom of Fig. 353. It will be observed that the armature carries two commutators, one of which is used when the armature is driven by the engine, and when the device serves as a current generator, the other being employed when the operating conditions are reversed and the electrical machine is acting as a motor to turn over the engine crankshaft. When the device is driven as a generator the small sliding pinion on the short end

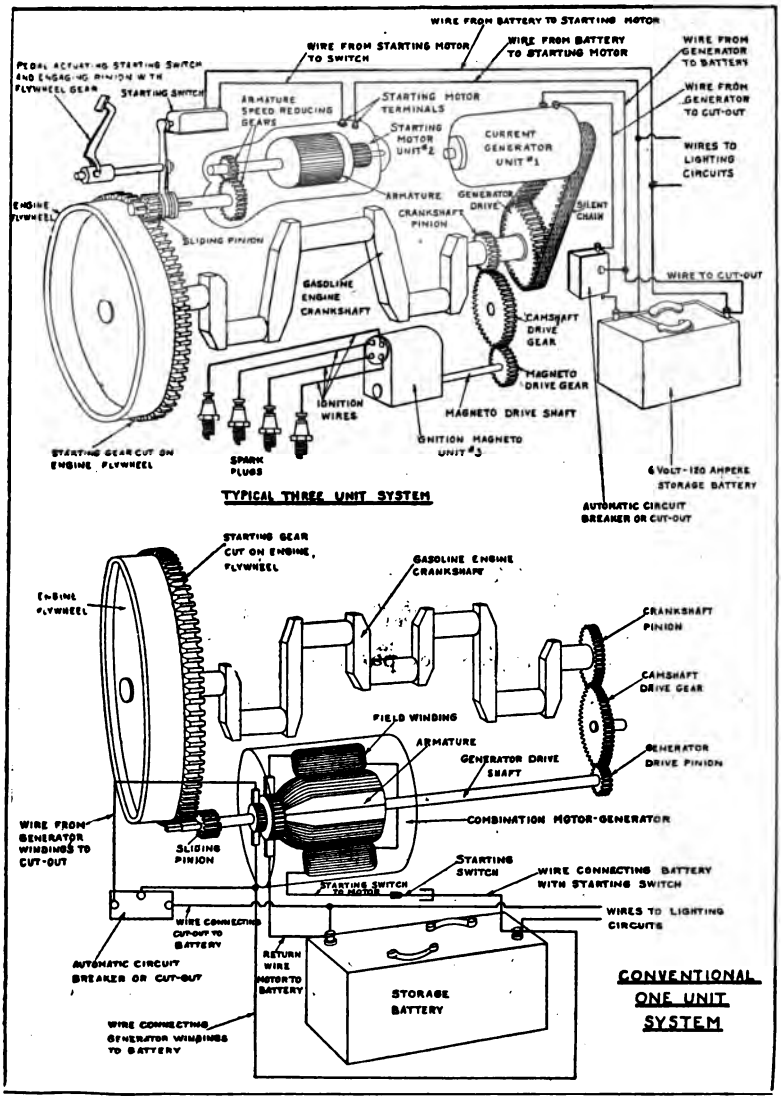


Fig. 353.—Diagrams Showing Relation of Parts of Typical Electrical Starting Systems. That at Top is a Three Unit while that Depicted Below is a One Unit Form.

of the shaft is out of engagement with the spur gear cut on the flywheel exterior. When it is desired to start the engine the spur gear is meshed with the member cut on the flywheel and the current from the storage battery is directed to the windings of the electric machine which becomes a motor and which turns over the engine crankshaft. When the device is working as a generator the current that is developed goes to the storage battery, and from that member to the various current consuming units.

Sometimes the motor and generator are combined in one casing and the system so provided is erroneously called a "one unit" system. In reality such a system is a two unit system, because the electrical machines are uni-functional instead of performing a dual function as does the combined-motor-generator at the right of the illustration. The wiring of the one unit system is shown in simplified form and should be easily followed by any motorist.

Q. Outline arrangement of parts of "two unit" system.

A. The parts of a two unit starting and lighting system are shown at Fig. 353. This system is sometimes called a "three unit" system, on account of having a source of independent current supply for ignition purposes. This is shown as fitted to the Overland six-cylinder engine at Fig. 354. As will be observed, the generator in the diagram is driven from the motor crankshaft by silent chain connections, one of the terminals passing through the cut-out device and to the storage battery, the other terminal running directly to the storage battery terminal having a short by-pass or shunt wire attached to the cut-out. All the time that the engine is running the generator is delivering electricity to the storage battery.

It will be seen that the storage battery is also coupled to the lighting circuits which are shown in a group at the right of the illustration, and to the electric starting motor as indicated. One of the storage battery terminals is joined directly to the switch terminal by a suitable conductor, the other goes to one of the terminals on the starting motor, while the remaining terminal of the starting motor goes to the switch. In this system, when the small sliding pinion is meshed with the flywheel gear, the switch

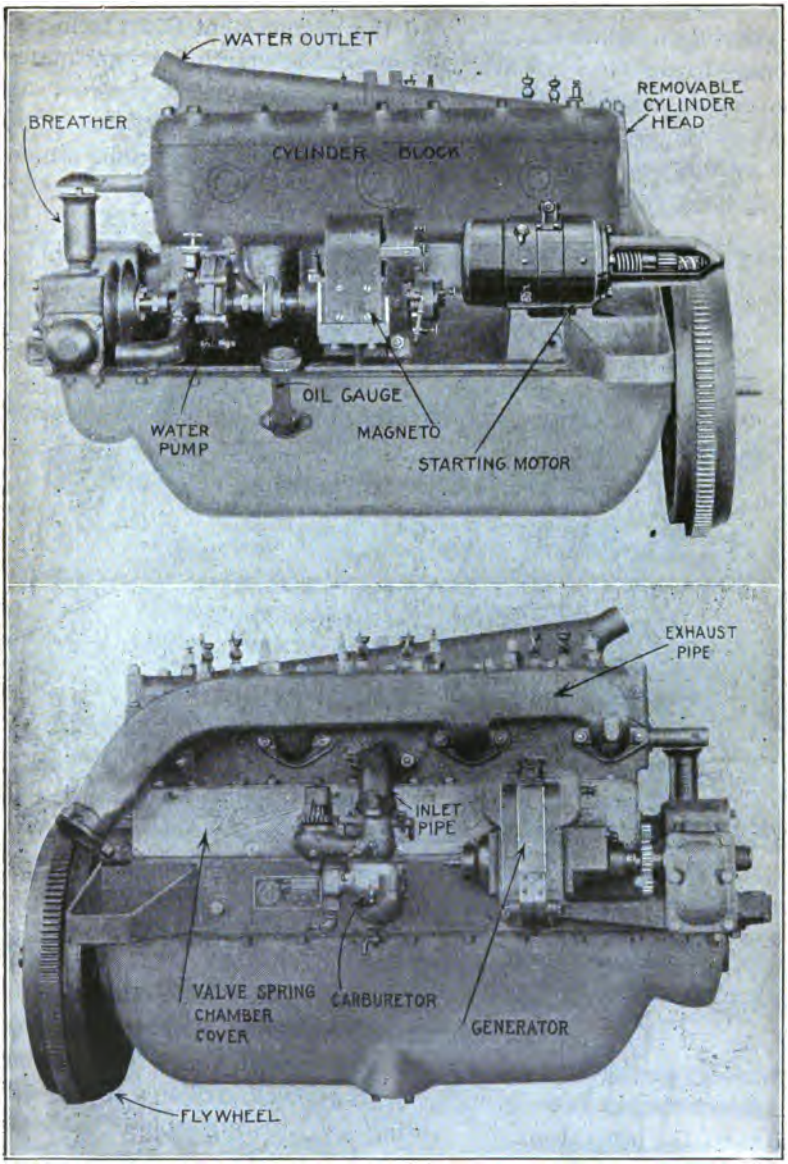


Fig. 354.—Illustration Showing Location of Starting, Lighting and Ignition Units on the Overland Six Cylinder Engine.

is thrown on simultaneously, and the current that flows from the storage battery through the windings of the starting motor rotates the engine crankshaft by means of reduction gears shown. As soon as the engine starts the foot is released and a spring pulls the switch out of contact, and also disengages the sliding pinion from the flywheel gear.

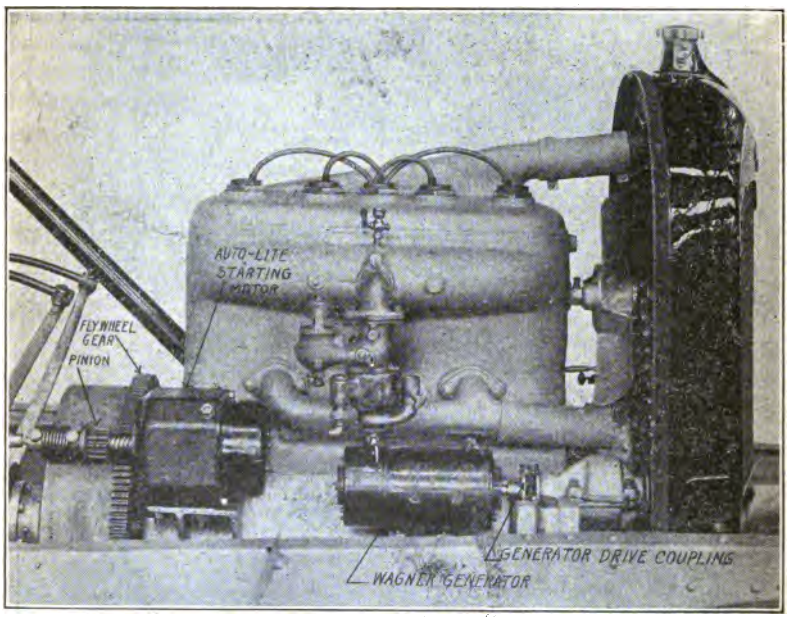


Fig. 355.—Moline-Knight Power Plant Showing Application of Starting Motor with Automatic Pinion Shift and Method of Driving Generator.

Q. What is the difference between a "three unit" and the others described?

A. In referring to a system as a one unit system of lighting, starting and ignition, one means that all of these functions are incorporated in one device, as in the Delco system. If one unit is used for generating the lighting and starting current, and also is reversible to act as a motor, but a separate ignition means is provided such as a high tension magneto, the system is called a

"two unit" system. The same designation applies to a system when the current generating and ignition functions are performed by one appliance, and where a separate starting motor is used. The three unit system is that in which a magneto is employed for ignition, a generator for supplying the lighting and starting current, and a motor for turning over the engine crankshaft. Before describing the individual systems it would be well to review briefly the various components common to all systems.

The actual appearance of a motor fitted with a two unit motor starting ignition and lighting system is shown at Fig. 355. It will be observed that the generator is driven from the pumpshaft extension by a leather universal joint, while the starting motor is mounted at the back end of the crankshaft in such a position that the automatic sliding pinion may be brought into engagement with the flywheel driving gear.

Q. What voltage current is usually employed in connection with electric starting and lighting systems?

A. Electrical starting systems are usually operated on either six or twelve volt current, the former being generally favored because the six-volt lamps use heavier filaments than those of high voltage, and are not so likely to break, due to vibration. It is also easier to install a six volt battery, as this is the standard voltage that has been used for several years for ignition and electric lighting purposes before the starting motors were applied. Some systems in which the motor-generator is part of the flywheel use twenty-four volt or twelve cell batteries.

Q. What is the purpose of the generator?

A. The generator, as is apparent from its name, is utilized for producing current. This is usually a miniature dynamo patterned largely after those that have received wide application for generating current for electric lighting of our homes and factories. The generators of the different systems vary in construction. Some have a permanent magnetic field, while others have an excited field. In the former case permanent horseshoe magnets are used as in a magneto. In the other construction the field magnets, as well as

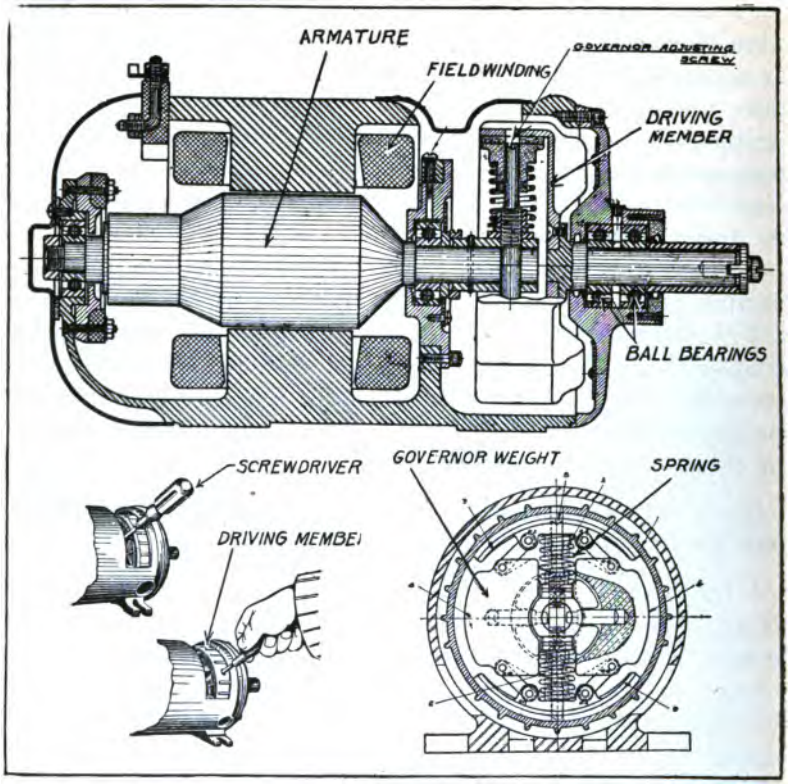


Fig. 356.—Sectional View of Latest Pattern, Gray & Davis Governed Dynamo, Showing Construction of Governor and Method of Adjusting.

the armature, are wound with coils of wire. In all cases the dynamo or generator should be mechanically driven from the engine crankshaft either by means of a direct drive, by silent chain, or through the medium of the timing or magneto operating gears. Belts are apt to slip and are not reliable.

Q. What is the storage battery for?

A. All the current produced by the generator and not utilized by the various current consuming units such as the lamps, ignition system, electric horn, etc., is accumulated or stored in the storage

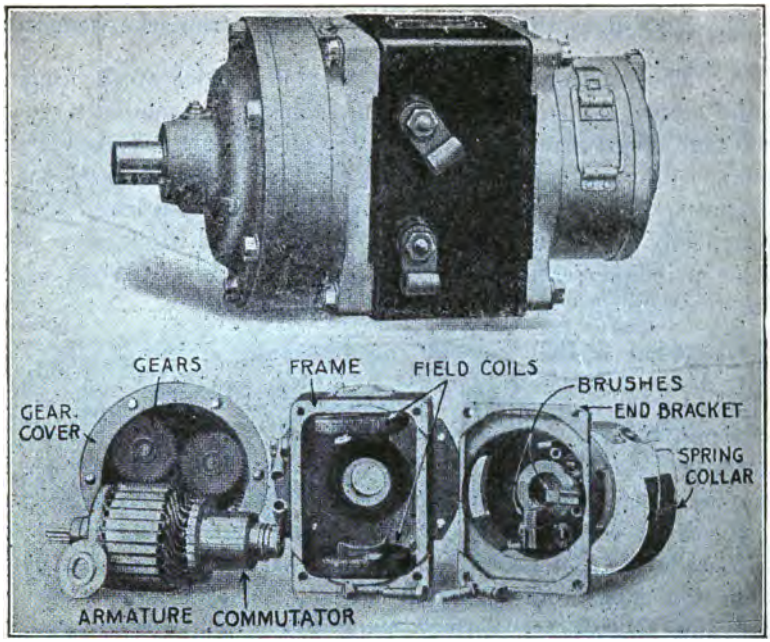


Fig. 357.—One Type of Westinghouse Starting Motor and Parts Comprising the Assembly.

battery, and kept in reserve for starting or lighting when the engine is not running or for lighting and ignition when the car is being run at such low speed that the generator is not supplying current. Storage batteries used in starting systems must be of special design in order to stand the high discharge and to perform efficiently under the severe vibration and operating conditions incidental to automobile service. The storage battery may be installed on the running board of the automobile, under the body, or under the front or rear seat, the location depending upon the design of the car and the degree of accessibility desired. The best practice is to set the storage battery in a substantial carrying case held by rigid braces attached to the frame side and cross members. If the battery should be set under the tonneau floor boards, a door must be provided in these to give ready access to the battery.

Q. How does the starting motor differ from the generator?

A. The starting motor, which takes the place of the common hand crank, is operated by current from the storage battery, and the high speed armature rotation is reduced to the proper cranking speed by reduction gears of the different forms to be described in proper sequence. The construction of the starting motor is practically the same as that of the dynamo, and it operates on the same principle, except that one instrument is a reversal of the other.

Q. What is the "cut-out" or automatic circuit breaker?

A. In order to secure automatic operation of a lighting and starting system several mechanical and electrical controls are needed, these including the circuit breaker, the governor, which may be either mechanical or electrical, and the operating switches. The circuit breaker is a device to retain current in the storage battery under such conditions that the battery current is stronger than that delivered from the generator. If no circuit breaker was provided the storage battery could discharge back through the generator winding. The circuit breaker is sometimes called a "cutout." The circuit breaker is usually operated by an electro magnet, and may be located either on the generator itself or any other convenient place on the car, though in many cases the circuit breakers are usually mounted on the back of the dashboard. This device is absolutely automatic in action and requires but little attention.

Q. How is the current output of the generator controlled?

A. The governors are intended to prevent an excessive output of current from the generator when the engine runs at extremely high speed. Two types are used: one mechanical, operated by centrifugal force as at Fig. 356, and the other electrical as depicted at Fig. 358. The former is usually a friction drive mechanism mounted in the generator shaft which automatically limits the speed of the dynamo armature to a definite predetermined number of revolutions per minute. The maximum current output is thus

held to the required amount independently of the speed at which the car is being driven. The use of this device minimizes the pos-

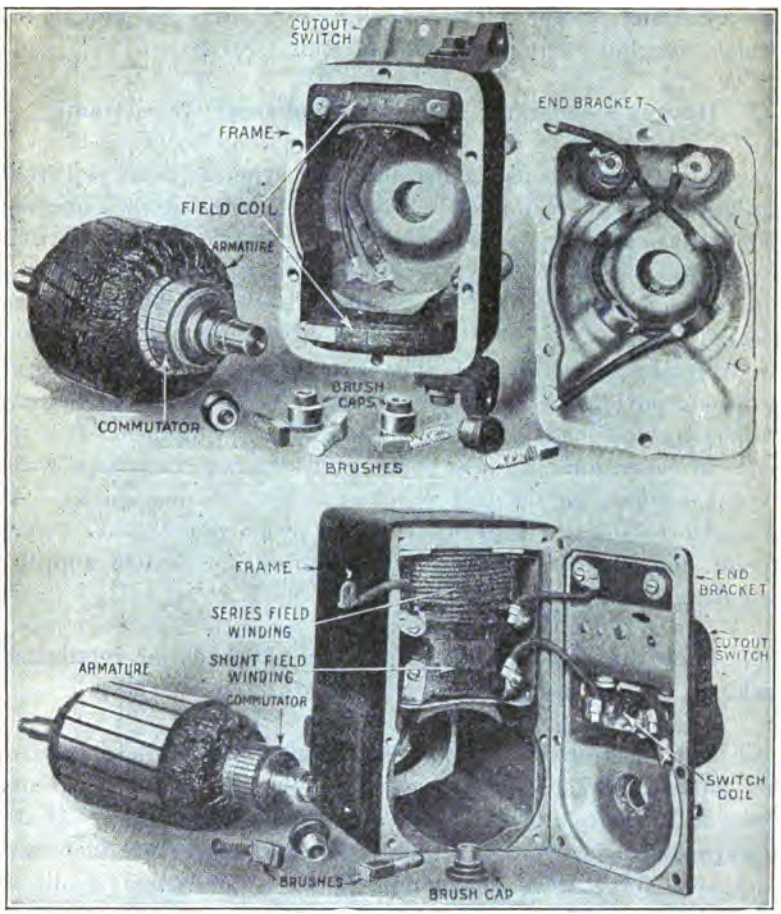


Fig. 358.—Westinghouse Current Generators Dismantled to Show Interior Construction.

sibility of overheating the generator or overcharging the battery at high car speeds. The electrical system of governing does not affect the speed of the armature, but controls the output of the

generator by means of armature reaction, a reversed series field winding or weakening the magnetic field in some way when the engine speed is excessive. The governors usually permit a maximum generator output of from ten to twelve amperes, though the normal charging current is less than this figure.

Q. How is a generator wound for "inherent" regulation?

A. The Westinghouse generators for example, with inherent regulation have a compound field winding. The battery charging current passes through the series winding in such direction that any increase in the battery charging current tends to reduce the voltage generated, so that the battery is never charged at an excessive rate. When the lights are burning, however, current flows through this series winding in the reverse direction, increasing the output of the generator and causing it to assist the battery in carrying the load. With the usual lamp equipment, this increase in generator output is sufficient to operate the lamps without any demand on the battery at ordinary running speeds. At low speeds the battery supplies a certain proportion of the lighting current, and when the engine is not running, the battery supplies the entire demand.

Q. How do generators with automatic potential regulators work?

A. The generators with automatic potential regulators maintain constant voltage regardless of whether the battery is connected to the system or not. The characteristics are such that the battery-charging current tapers off as the battery charge increases, being very large when the battery is in a discharged condition and of low value when the battery is fully charged. The voltage is independent of the speed and the amount of lighting load. The regulator consists of a vibrating armature that intermittently short-circuits a high resistance in series with the shunt field winding of the generator, the length of the short-circuit period depending on the load on the generator.

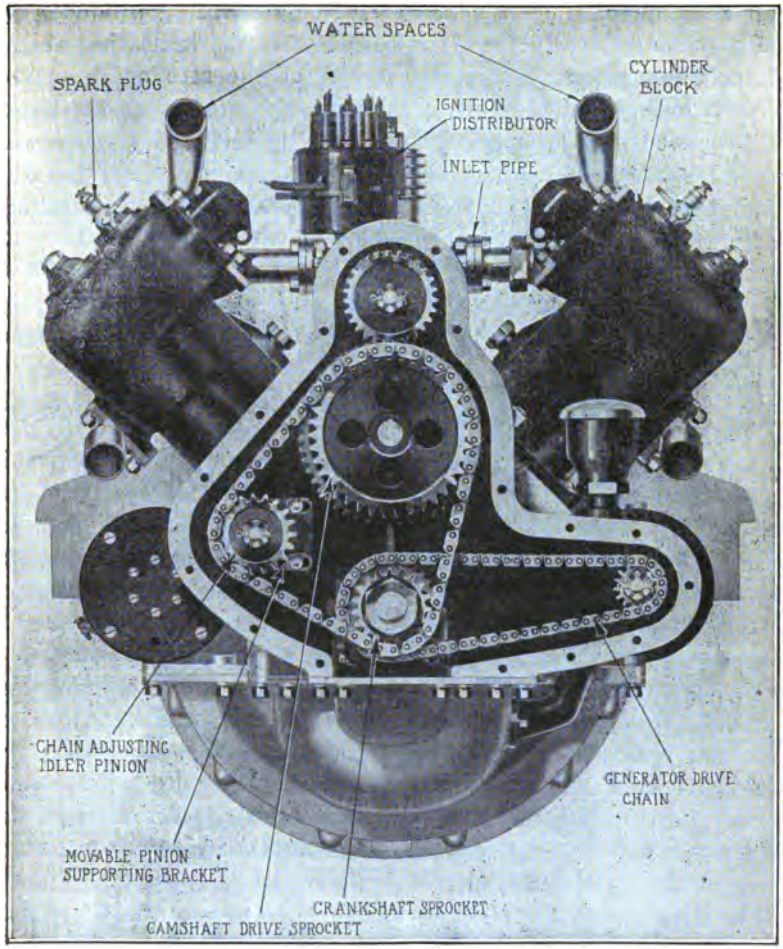


Fig. 359.—Front View of King Eight Cylinder Power Plant Showing Silent Chain Drive to Generator.

Q. How does the motorist know that an electrical system is working correctly?

A. In practically all systems an amperemeter is mounted on the dash so that it can be readily inspected by the driver, this

indicating at all times the amount of current being produced by the dynamo or drawn from the battery. If the indicating needle of the amperemeter points to the left of the zero point on the scale, it means that the battery is furnishing current to the lights or other current consuming units or discharging. When the needle points to the other side of the scale, it means that the generator is delivering current to the battery which is charging it, the amount of charge or discharge at any time can be read from the scale on the face of the amperemeter. Some of these instruments have the words "charge" and "discharge" under the scale in order to enable the operator to read the instrument correctly.

Q. What types of switches are used and how do they differ?

A. Another important element is the lighting switch, which is usually mounted at some point within convenient reach of the car driver. This is often placed on an instrument board on the back of the cowl in connection with other registering instruments. As ordinarily constructed, the switches are made up of a number of units, and the wiring is such that the head, side and tail lamps may be controlled independently of each other. For simplicity and convenience of installation, the switch is usually arranged so that all circuits are wired to parallel connecting members or "busbars" placed at the rear of the switch. In some cars, as the latest Overland and the White models, the switch units are placed on the steering column. As but little current passes through the lighting switch the contacts are not heavy in construction as are those of the starting switch.

The function of the starting switch is to permit the current to flow from the storage battery to the starting motor, when it is necessary to start the car. It is arranged usually so as to be readily operated by the foot and is nearly always installed at some convenient position on the toe board of the car. As we have previously shown, the starting switch is often interlocked with the starting motor gearing so that the operation of engaging the gear with the flywheel and of turning on the current to the starting motor are accomplished simultaneously. The lighting and

motor starting wiring systems are independent of each other, and may be easily found as that used to convey the high amperage starting current is of heavy round single conductor cable, while the lighting wiring is usually a light multiple strand cable. In order to prevent chafing and depreciation of the insulation the wiring is often protected by conduits of a flexible metal tubing, and the terminals are extremely heavy and well adapted to resist the vibration which is unavoidable in automobiles.

Q. How are current generators driven?

A. When electric lighting was first applied to automobiles it was not considered necessary to drive the generators by positive connection, and the early devices were furnished with pulleys for flat or V belt drive. At the present time it is considered highly important to provide a positive mechanical connection that will not slip between the generator and the engine crankshaft. The common systems where the generator is a separate unit from the starting motor and in those forms where the starting and generating functions are combined, involve a connection with the motor crankshaft through some form of gearing. As shown in Fig. 355, the generator is driven by means of a leather universal joint connection with an extension of the pump shaft. The motor crankshaft imparts its power through the camshaft timing gear to the small pinion utilized in driving the water pump. In some generator applications a belt is used, and at Fig. 359 the armature is rotated by silent chain connection with a gear on the motor crankshaft. There is not the diversity of drives for the generator as there is in the methods of connecting the starting motor to the end of the crankshaft.

Q. What are the advantages of silent chain drive?

A. In describing the advantages of silent chain drive the Dyneto Company writes as follows: "The exact type of drive selected must, of course, depend upon conditions. If possible, use a silent chain drive, direct to the crankshaft, with a suitable casing so that the chain can run in oil with all dirt excluded. In our opinion this will give the most quiet, durable and efficient

drive obtainable. We recommend, when space allows, the use of chains of ½″ pitch x ½″ width. When sprockets of small diameter must be used, chains of ⅜″ pitch x 1″ width will be satisfactory. Sprockets of less than 15 teeth should *never* be used; 17 teeth would be much better. The efficiency of a good chain drive, well installed, is from 94 to 96%. If a gear drive is used, the gears must be of the best material and large enough to stand up under the enormous strains of starting. It is usually impossible to design a suitable gear drive of single reduction, and where three of four gears are used the drive is apt to be noisy, and certainly will be very inefficient. In tests of drives, using four gears in the train, spiral cut teeth, we have found an efficiency of less than 65%. A useless waste of 35% makes it necessary to use a larger starter, a larger battery, larger wires, and in fact the whole outfit must be much larger than otherwise would be necessary."

Q. How is the starting motor connected to the engine crankshaft to rotate it for starting?

A. In order to show the variety of driving means used in connecting the starting motor to do the work of turning over the engine crankshaft, the leading systems have been grouped in one illustration at the top of Fig. 360. Starting from the front of the motor, the first method shown is by means of a worm gear initial or primary reduction and chain connection from the worm-driven shaft to the motor crankshaft. In some cars the worm reduction is used having the starting motor mounted at the side of the change speed gear box instead of attached to the motor crankshaft. The reduction in speed may be by means of the spur gears and chain, as shown at A-2, or by a chain to a shaft connected with the timing gear, as in A-3. The method at A-4 is a very popular one, including a reduction to an intermediate shaft, which carries a sliding pinion designed to engage the gear on the flywheel rim. The method at A-5 is used with the Rushmore starter, the pinion being brought into direct engagement with the gear on the flywheel by the axial movement of the armature when the current is supplied to the field winding. The method

at A-6 permits of attaching the starting motor securely to the frame side member at a point near the gear box, where it will be out of the way and not interfere with the accessibility of the power plant. When mounted in this manner the drive is by a double universally jointed shaft to a small silent chain sprocket,

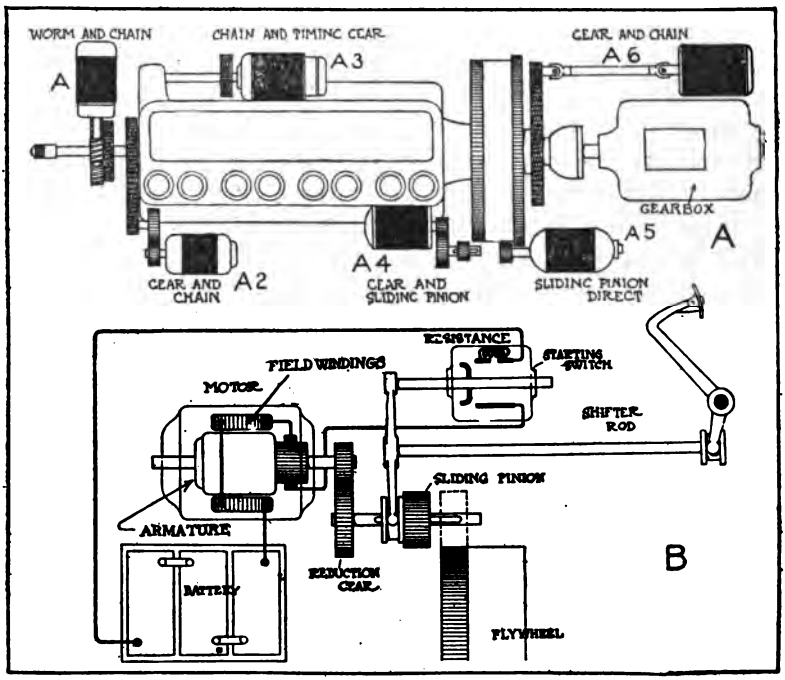


Fig. 360.—Diagram Showing Methods of Transmitting Power of Starting Motor to Gasoline Engine at A. Simplified Diagram at B Depicts Means of Interconnecting Starting Switch and Motor Starting Gear.

which connects to a much larger member attached to the engine flywheel or crankshaft.

Q. What is the most popular mechanical pinion shift for starting motors?

A. The complete system shown at Fig. 360-B, is the next most popular of all that have been used. This shows the application

of the starting-motor, outlined at A-4. The mechanical interlock between the sliding pinion on the intermediate shaft and the starting switch is clearly shown. Before the pinion engages the gear on the flywheel rim the switch makes contact, but owing to the resistance interposed in circuit the motor will turn slowly to permit of more ready engagement of the sliding pinion. As soon as the pinion is fully engaged with the large gear the resistance is cut out and the motor draws what current it needs from the storage battery, this being enough to produce the torque necessary to turn over the engine flywheel and the crankshaft to which it is attached at such speed as will produce prompt starting. A system of this nature used on the Hupmobile in connection with the Bijur starter is shown at Fig. 361. In this the pinion is shifted by a spring connection as outlined at *A* instead of a direct rigid coupling. This makes it easier to engage the pinion as the switch can make contact as at *D* and the spring will draw the pinion in mesh. The spring is also useful under the conditions shown at *B* where the pinion engages readily but the switch has not yet made contact.

Q. What is an "overrunning" clutch and what is its purpose?

A. The construction of a typical overrunning clutch is clearly shown at Fig. 362. The electric starting motor is secured to a base on the crankcase of the gasoline engine and the motor power is imparted through the medium of the small gear *F* carried by the armature shaft. This drives gear *E*, which turns at a lower speed on account of being larger, and that in turn engages with gear *D*, which is still larger in diameter. The small pinion *C*, which turns much slower than the motor pinion *F*, meshes with the large gear *B* attached to the clutch body. The use of this gearing provides a reduction of 40 to 1, which means that gear *F* must make 40 revolutions to one of the clutch body.

The ratchet or driven member of the overrunning clutch *L* is pinned to the engine crankshaft and revolves with it when the motor is operating, rotating inside of the gear *B*, having a bearing at *K* and turning in the direction of the arrow. The member *L* has three flat surfaces, *M*, cut at an angle to the inside of the

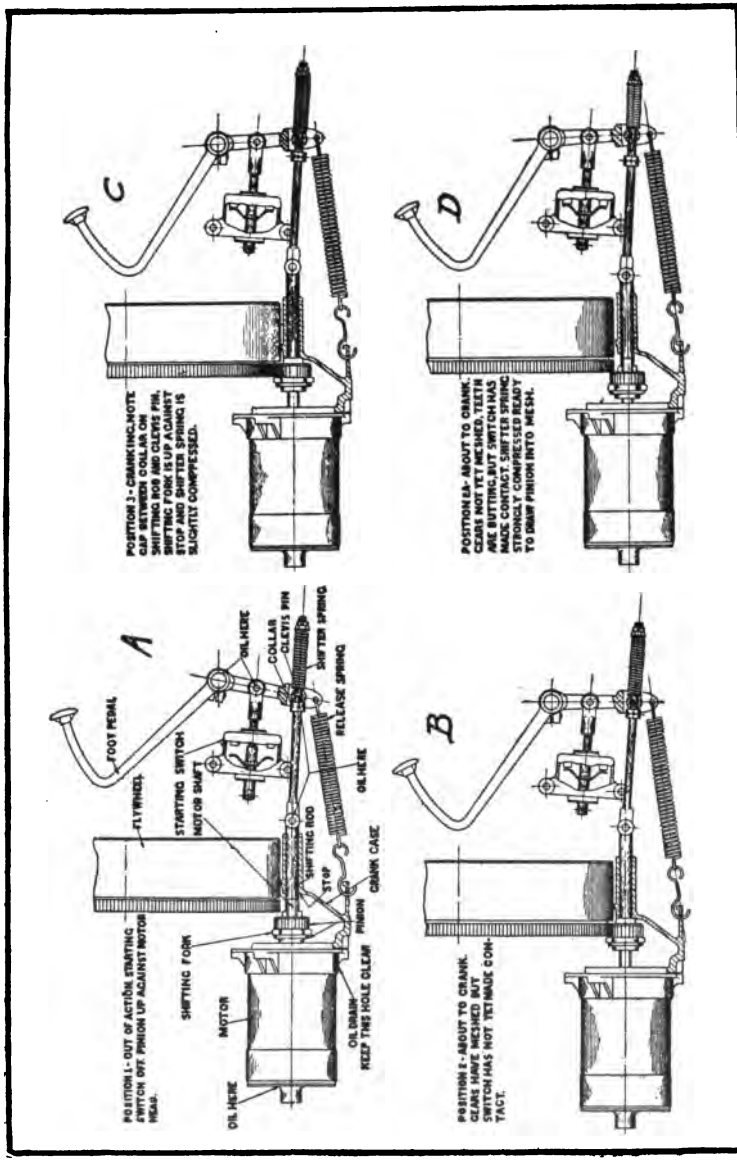

A
B
C
D
FOOT PEDAL
FLYWHEEL
STARTING SWITCH
MOTOR SHAFT
OIL HERE
COLLAR
CLEVIS PIN
SHIFTER SPRING
RELEASE SPRING
SHIFTING ROD
STOP
CRANK CASE
PINION
SHIFTING FORK
MOTOR
OIL DRAIN
KEEP THIS HOLE CLEAR
POSITION 1 - OUT OF ACTION. STARTING PINION OFF. PINION UP AGAINST MOTOR.
POSITION 1 - ABOUT TO CRANK. GEARS HAVE MESHED BUT SWITCH HAS NOT YET MADE CONTACT.
POSITION 2 - CRANKING. NOTE GAP BETWEEN COLLAR ON SHIFTING FORK AND CLEVIS PIN. SHIFTING FORK HELD UP AGAINST STOP AND SHIFTER SPRING IS SLIGHTLY COMPRESSED.
POSITION 2A - ABOUT TO CRANK. GEARS NOT YET MESHED, TEETH ARE BUTTING, BUT SWITCH HAS MADE CONTACT. SHIFTER SPRING STRONGLY COMPRESSED READY TO DRAW PINION INTO MESH.

Fig. 361.—Showing How the Starting Switch and Shifting Pinion are Interconnected in the Bijur-Hupmobile Starting System.

gear *B*. On each of these a hardened steel roller, *A*, is held inside of the gear by a light spring and against the flat surface of the member *L*. The roller travels with the clutch and runs free against the side of the gear *B* when the engine is in motion and when the starting gears are idle. As soon as the current is directed to the electric starting motor, the three rollers are bound between the

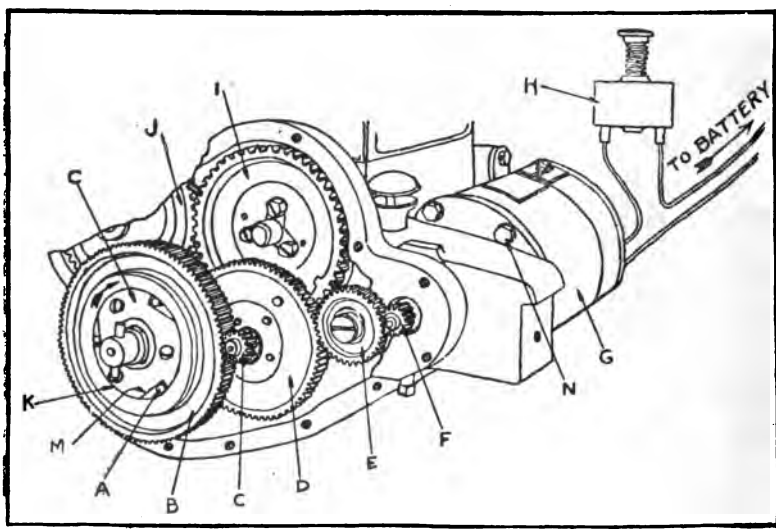


Fig. 362.—Diagram Showing Construction of Typical Overrunning Clutch.

clutch body and the rachet member carrying them and the crankshaft is driven until such time as the engine speed increases sufficiently to overrun that of the member attached to the crankshaft.

Q. What is the "automatic" pinion shift?

A. This is what is now becoming the most popular method of connecting the starting motor to the engine. A pinion is provided with a spiral thread inside and fits a corresponding thread on the motor shaft. The angle of the thread is such that as the switch

is depressed and the motor started, the rotation of the armature shaft screws the pinion in and meshes it with the flywheel gear. As soon as the gasoline engine starts, it automatically shifts the pinion out of engagement with the flywheel gear teeth.

Q. What is the Delco starting, lighting and ignition system, and how does it operate?

A. One of the most popular systems is that shown at Fig. 364, which is a complete starting, lighting and ignition system using a single unit to perform the three functions. This is the Delco system and was the first really practical self-starting assembly to receive general application. It is of a single wire or ground type which means that one side of the storage battery is directly connected to the frame of the car, only one wire being carried to the various lamps and other current consuming units. The motor generator is a single unit type and includes the ignition distributor and timer, which is built in the front end of the housing. The operation of the motor generator will be more clearly understood if one views it first merely as an electric motor, suitably connected with the engine to turn the crankshaft and then by an ingenious shifting of the internal mechanism as a generator for charging the storage battery and to furnish current for the lights and ignition, at this time being so arranged that the generator is turned by the engine.

When used as a motor, it operates on the series wound principle and has a spur gear pinion upon the end of the armature shaft nearest the fly-wheel. Interposed between this pinion and the gear teeth cut in the face of the fly-wheel is a pair of gears adapted to slide along and revolve upon an intermediate shaft. This sliding action results in the larger of the gears engaging with the motor pinion, while the smaller one meshes with the gear teeth on the fly-wheel. A one way starting clutch is incorporated inside of this set of gears and is for the purpose of permitting the engine to run ahead of the motor during the short time that the gears are meshed after the engine fires and is running under its own power. The total gear ratio between the armature shaft and the engine shaft is approximately 20 to 1. This means that the

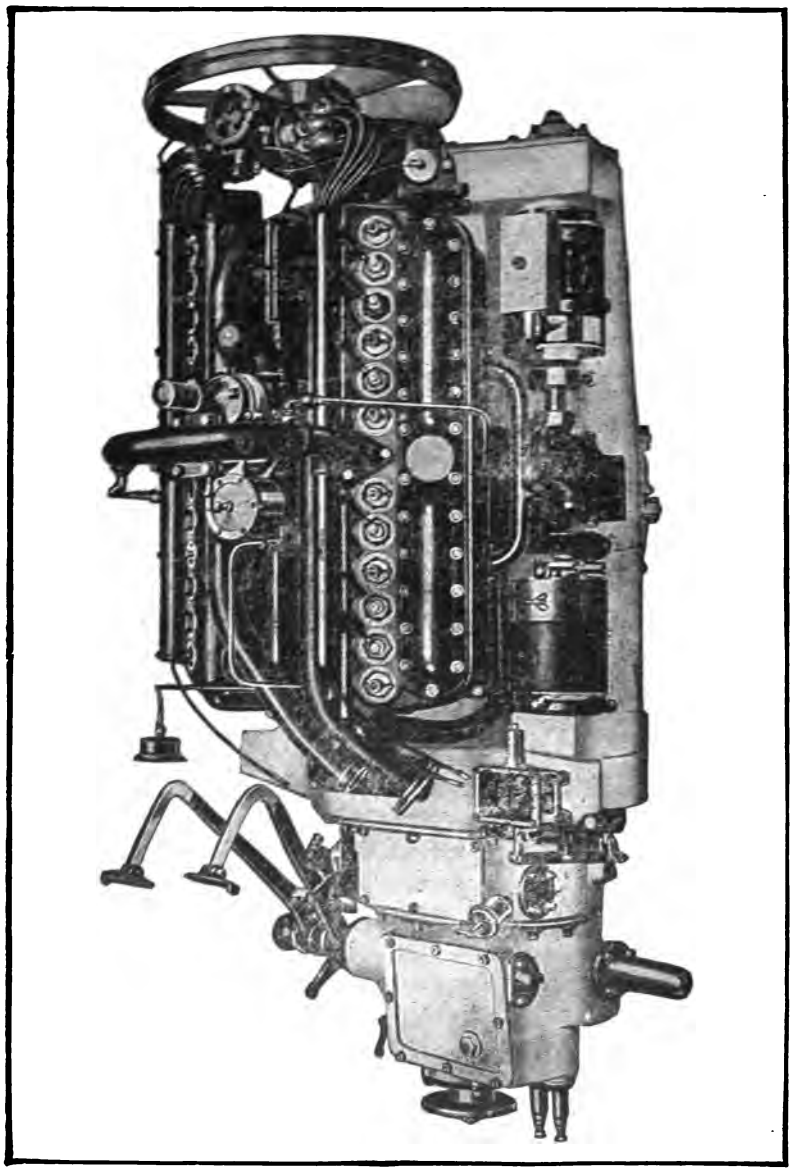


Fig. 363.—View of Packard Twin Six Motor Showing Location of Generator and Starting Motor; Also Depicts How Compactly Parts May Be Arranged at the Side of the Engine Crank Case. The Special Delco Twin Six Ignition Unit is Shown at the Front of the Engine.

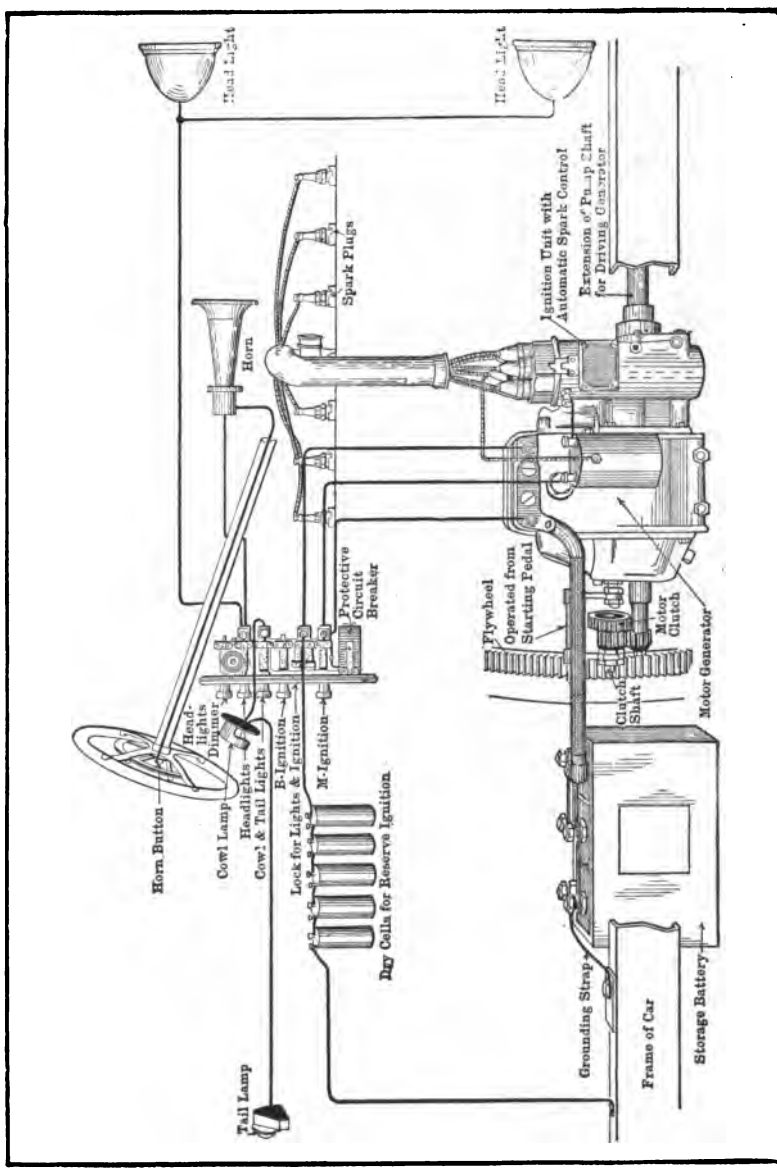


Fig. 364.—The Delco One Unit Starting, Lighting and Ignition System.

armature makes twenty revolutions to turn the engine over once, and assuming a motor speed of 2,000 R.P.M., the engine will be cranked over 100 R.P.M., or considerably faster than is possible by hand.

When the unit is generating current for charging the battery it is a simple shunt wound generator. In this case it is driven from the engine by an extension of the pump shaft. The generator is driven at crank shaft speed and in order to compensate for the higher ratios when the unit is in starting relation to the engine a second one-way driving clutch is provided adjacent to the forward housing. This permits the armature to run ahead of the driving shaft during the cranking operation. When a starting pedal is pushed forward it shifts the brushes from the generator commutator and engages the brushes of the motor commutator, there being two commutators on the armature. Whenever the starting pedal is released the motor brushes are lifted from their commutator and generator brushes are dropped on their commutator.

A cut-out relay is located on the rear end housing of the motor generator, this instrument performing a double function. During the initial starting operation it is closed mechanically to complete the circuit between the storage battery and the armature, and it also automatically closes the circuit between the generator and storage battery when the generator voltage is high enough to charge the battery. It opens the circuit when the generator slows down to prevent the battery discharging back through the generator windings. The latest type Delco system has a slightly different detail construction of the generator than those formerly used as it has a "third brush" inherent regulation of current output instead of an auxiliary voltage regulator.

Q. Describe the latest type Delco motor generator and its functions.

A. The motor generator which is located on the right side of the engine as at Fig. 365 is the principal part of the Delco System. This consists essentially of a dynamo with two field windings, and two windings on the armature with two commu-

tators and corresponding sets of brushes. In order that the ignition apparatus incorporated in the forward end of the machine may work when it is used as a starting motor, or as a generator for charging the battery and supplying the lights, horn and ignition, the ignition distributor is always driven in the same direction. This in no way affects the working of the generator, it being mounted in this

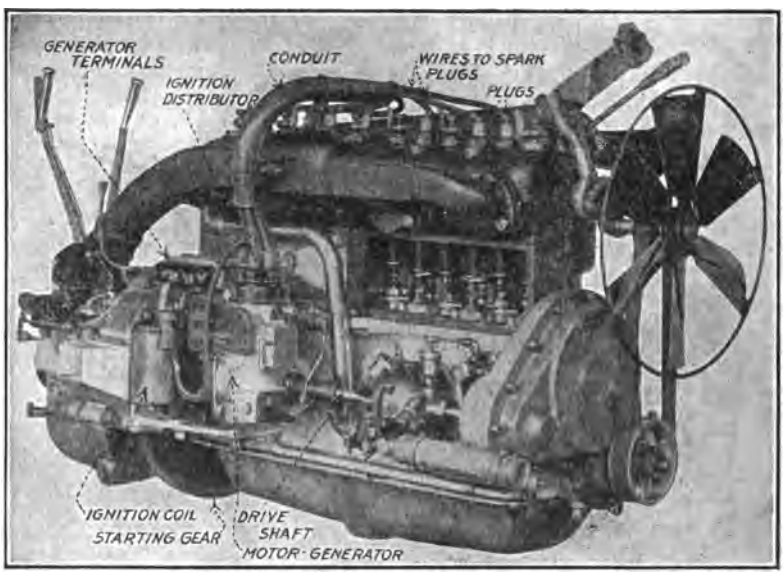


Fig. 365.—Application of Delco Motor Generator to 1916 Hudson Engine.

manner simply as a convenient and accessible mounting. In some cases it is independent.

The motor generator has three distinct functions to perform which are as follows: No. 1—Motoring the Generator. No. 2—Cranking the Engine. No. 3—Generating Electrical Energy.

Q. Describe the "motoring" function.

A. Motoring the generator is accomplished when the ignition button on the switch is pulled out. This allows current to come from the storage battery through the ammeter on the combination

switch, causing it to show a discharge. The first reading of the meter will be much more than the reading after the armature is

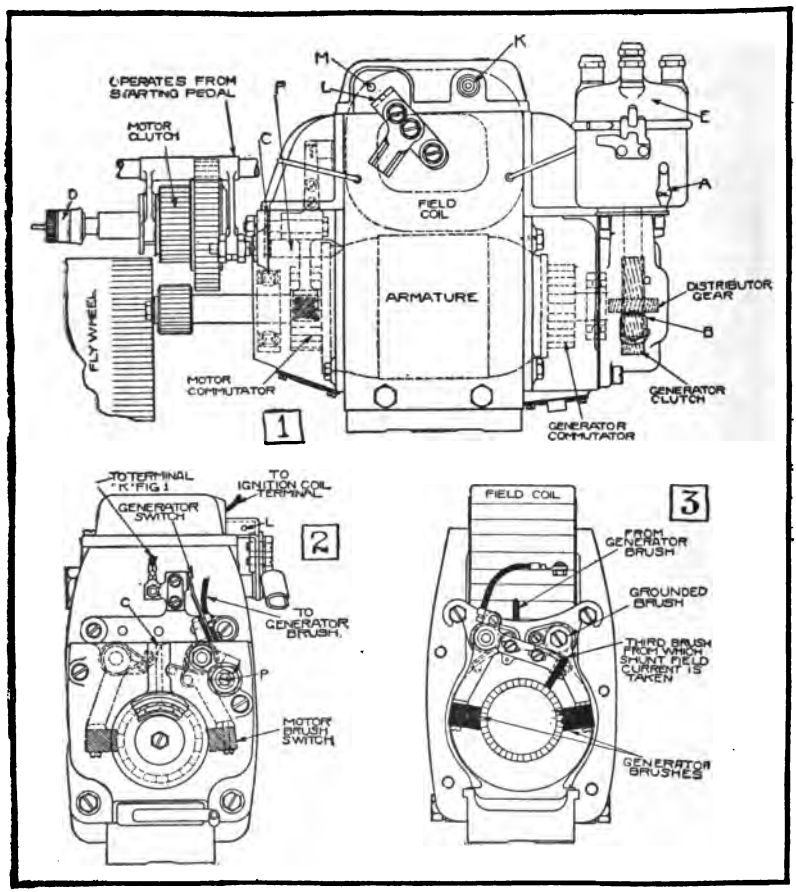


Fig. 366.—Diagrams Explaining Construction of Delco Motor Generator Having Third Brush Current Control.

turning freely. The current discharging through the ammeter during this operation is the current required to slowly revolve the armature and what is used for the ignition. The ignition current flows only when the contacts are closed, it being an inter-

mittent current. The maximum ignition current is obtained when the circuit is first closed and the resistance unit on the rear end of the coil is cold. The current at this time is approximately 6 amperes, but soon decreases to approximately 3½ amperes. Then as the engine is running it further decreases until at 1,000 revolutions of the engine it is approximately 1 ampere.

This motoring of the generator is necessary in order that the starting gears may be brought into mesh, and should trouble be experienced in meshing these gears, do not try to force them,

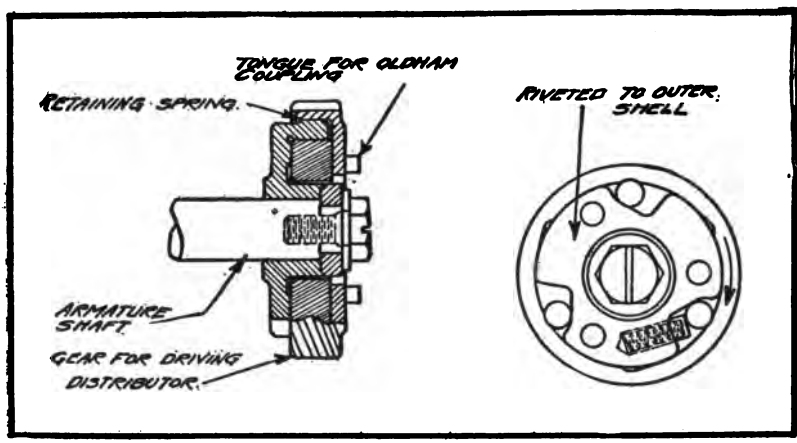


Fig. 367.—The Delco Overrunning Clutch.

simply allow the starting pedal to come back, giving the gears time to change their relative position.

A clicking sound will be heard during the motoring of the generator. This is caused by the overrunning of the clutch in the forward end of the generator which is shown in view 1, Fig. 366.

The purpose of the generator clutch is to allow the armature to revolve at a higher speed than the pump shaft during the cranking operation and permitting the pump shaft to drive the armature when the engine is running on its own power. A spiral gear is cut on the outer face of this clutch for driving the distributor. This portion of the clutch is connected by an Oldham coupling to the pump shaft. Therefore, its relation to the pump shaft is

always the same and does not throw the ignition out of time during the cranking operation. This clutch receives lubrication from the oil that is contained in the front end of the generator which is put in at *B* (view 1). This is to receive oil each week sufficient to bring the oil up to the level of the oiler. The arrangement of clutch parts is shown at Fig. 367.

Q. Describe the "cranking" operation.

A. The cranking operation takes place when the starting pedal is fully depressed. The starting pedal brings the motor clutch gears (view 1) into mesh and withdraws the pin *P* (views 1 and 2), allowing the motor brush switch to make contact on the motor commutator. At the same time the generator switch breaks contact. This cuts out the generator element during the cranking operation. As soon as the motor brush makes contact on the commutator a heavy current from the storage battery flows through the series field winding and the motor winding on the armature. This rotates the armature and performs the cranking operation. The cranking circuit is shown in the heavy lines on the circuit diagram (Fig. 368). This cranking operation requires a heavy current from the storage battery, and if the lights are on during the cranking operation, the heavy discharge from the battery causes the voltage of the battery to decrease enough to cause the lights to grow dim. This is noticed especially when the battery is nearly discharged; also will be more apparent with a stiff motor or with a loose or poor connection in the battery circuit or a nearly discharged battery. It is on account of this heavy discharge current that the cranking should not be continued any longer than is necessary, although a fully charged battery will crank the engine for several minutes.

During the cranking operation the ammeter will show a discharge. This is the current that is used both in the shunt field winding and the ignition current; the ignition current being an intermittent current of comparatively low frequency will cause the ammeter to vibrate during the cranking operation. If the lights are on the meter will show a heavier discharge. The main cranking current is not conducted through the ammeter, as this

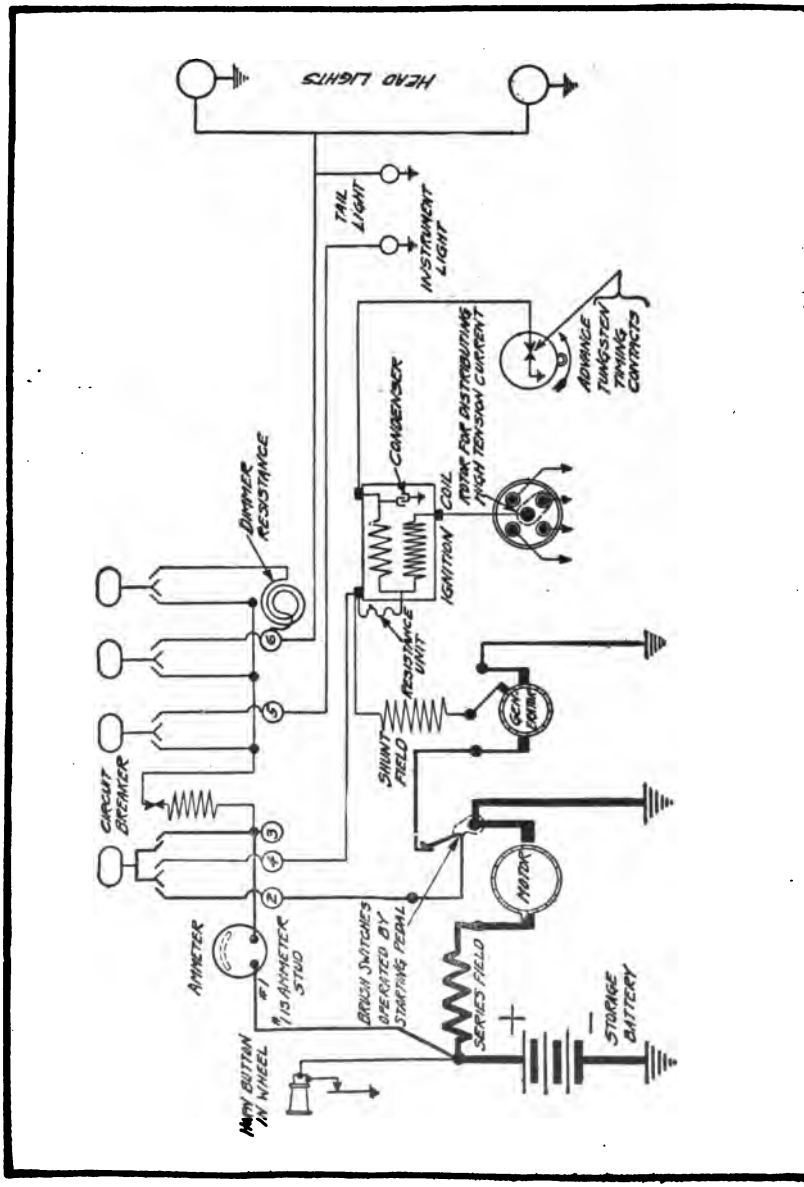


Fig. 368.—Wiring Diagram Showing Relation of Parts of 1916 Oakland-Delco Starting, Lighting and Ignition System.

is a very heavy current and it would be impossible to conduct this heavy current through the ammeter and still have an ammeter that is sensitive enough to indicate accurately the charging current and the current for lights and ignition. As soon as the engine fires the starting pedal should be released immediately, as the overrunning motor clutch is operating from the time the engine fires until the starting gears are out of mesh. Since they operate at a very high speed, if they held in mesh for any length of time, there is enough friction in this clutch to cause it to heat and burn out the lubricant. There is no necessity for holding the gears in mesh.

Q. What is the "Delco" motor clutch for and how is it lubricated?

A. The motor clutch operates between the flywheel and the armature pinion for the purpose of getting a suitable gear reduction between the motor generator and the flywheel. It also prevents the armature from being driven at an excessively high speed during the short time the gears are meshed after the engine is running on its own power. This clutch is lubricated by the grease cup *A*, shown in view 1, Fig. 366. This forces grease through the hollow shaft to the inside of the clutch. This cup should be given a turn or two every week.

Q. How does the "Delco" machine deliver electric energy?

A. When the cranking operation is finished the motor brush switch is raised off the commutator by the pin *P* when the starting pedal is released. This throws the starting motor out of action. As the motor brush is raised off the commutator the generator switch makes contact and completes the charging circuit. The armature is then driven by the extension of the pump shaft and the charging begins. At speeds above approximately 7 miles per hour the generator voltage is higher than the voltage of the storage battery which causes current to flow from the generator winding through the armature in the proper direction to charge the storage battery. As the speed increases up to approximately 20 miles per hour this charging current increases, but at the higher speeds

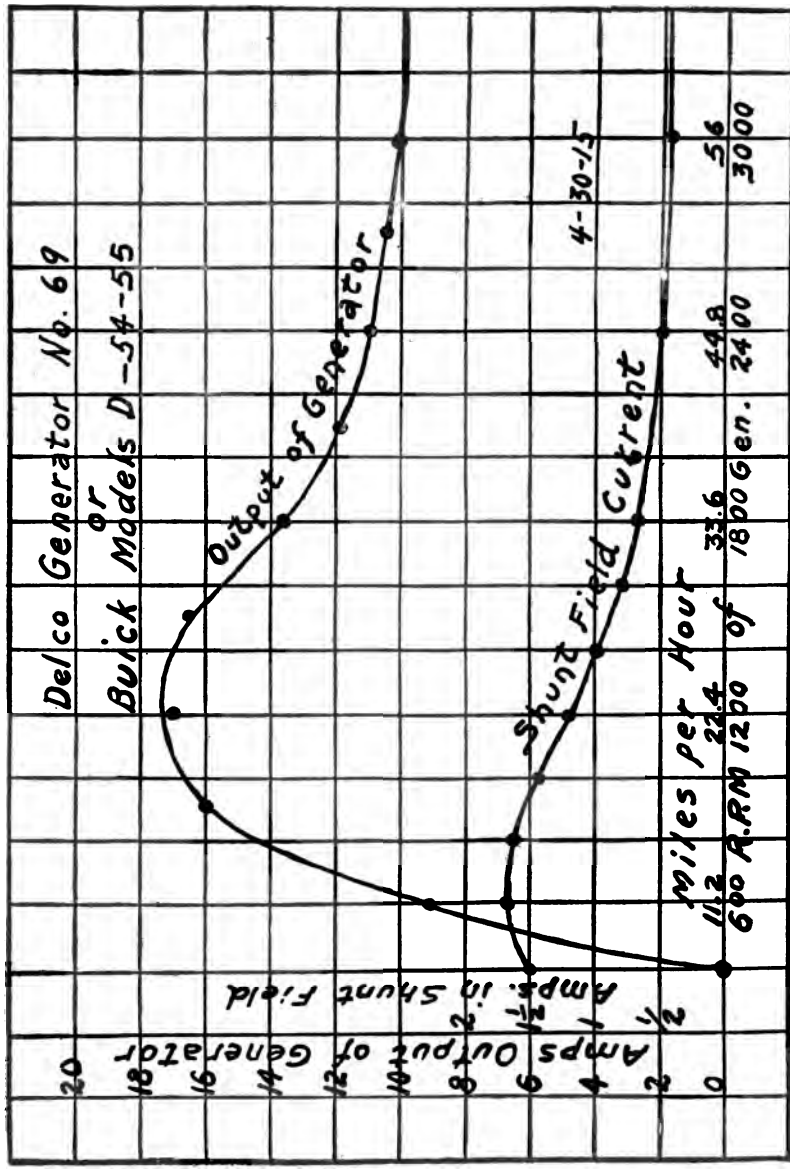


Fig. 369.—Curves Showing Output of Delco Generator No. 69 at Different Car Speeds.

the charging current decreases. The curve, Fig. 369, shows approximately the charging current that should be received for different speeds of the car. There will be slight variations from this due to temperature changes and conditions of the battery which will amount to as much as from 2 to 3 amperes.

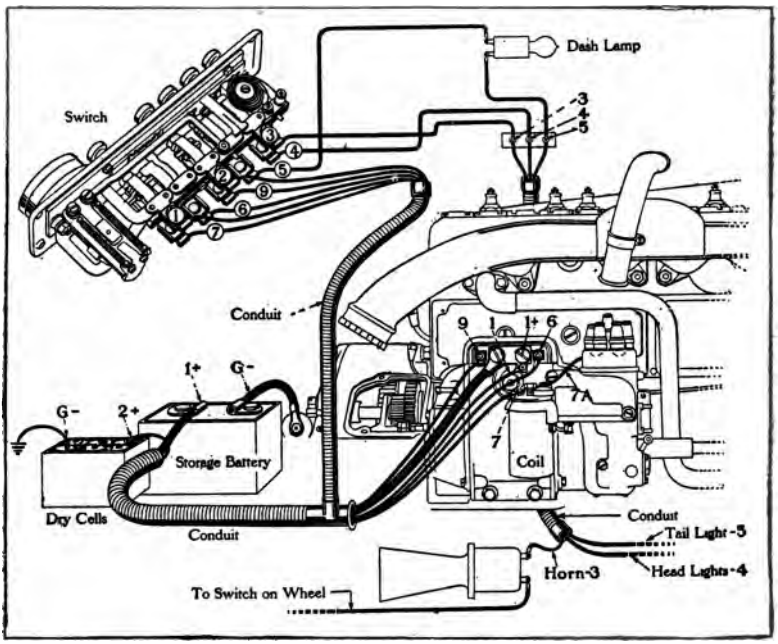


Fig. 370.—Non-Technical Wiring Diagram Showing Parts of the 1916 Delco-Hudson Ignition Starting and Lighting Systems.

Q. What points need lubrication on the "Delco" motor-generator?

A. There are five places to lubricate this Delco System. No. 1—The grease cup for lubricating the motor clutch (*D*, view 1, Fig. 366). No. 2—Oiler for lubricating the generator clutch and forward armature bearing (*B*). No. 3—The oil hole (*C*) for lubricating the bearings on the rear armature shaft. This is exposed when the rear end cover is removed. This should re-

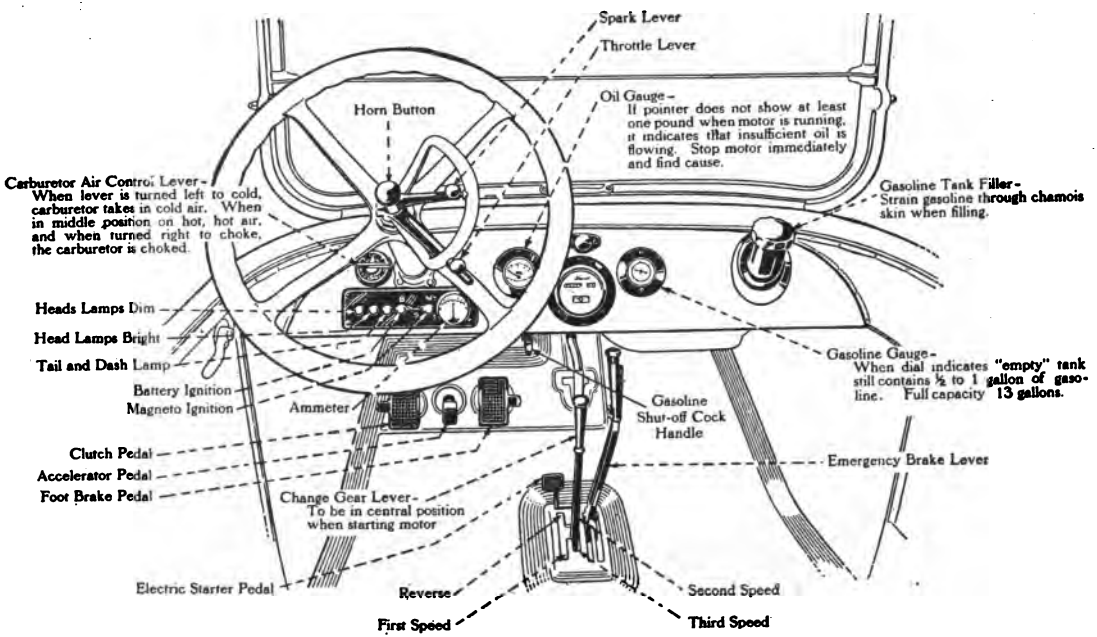

Spark Lever
Throttle Lever
Horn Button
Oil Gauge - If pointer does not show at least one pound when motor is running, it indicates that insufficient oil is flowing. Stop motor immediately and find cause.
Carburetor Air Control Lever - When lever is turned left to cold, carburetor takes in cold air. When in middle position on hot, hot air, and when turned right to choke, the carburetor is choked.
Gasoline Tank Filler - Strain gasoline through chamois skin when filling.
Heads Lamps Dim
Head Lamps Bright
Tail and Dash Lamp
Battery Ignition
Magneto Ignition
Ammeter
Gasoline Gauge - When dial indicates "empty" tank still contains ½ to 1 gallon of gasoline. Full capacity 13 gallons.
Gasoline Shut-off Cock Handle
Clutch Pedal
Accelerator Pedal
Foot Brake Pedal
Emergency Brake Lever
Change Gear Lever - To be in central position when starting motor
Electric Starter Pedal
Reverse
First Speed
Second Speed
Third Speed
Functions of Fittings and Levers in Drivers Compartment

Fig. 371.—Driver's Compartment of 1916 Hudson Showing Parts of the Various Controlling Elements.

ceive oil once a week. No. 4—The oil hole in the distributor, at *A*, for lubricating the top bearing of the distributor shaft. This should receive oil once a week. No. 5—This is the inside of the distributor head. This should be lubricated with a small amount of vaseline, carefully applied two or three times during the first 2,000 miles running of the car, after which it will require no attention. This is to secure a burnished track for the rotor brush on the distributor head. This grease should be sparingly applied and the head wiped clean from dust and dirt.

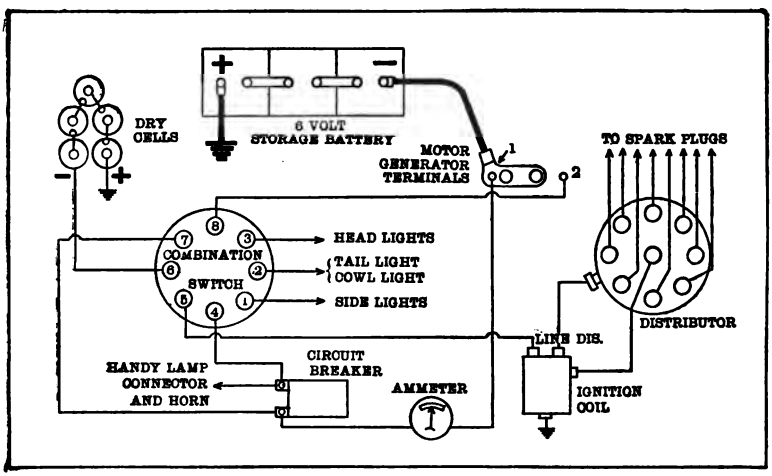


Fig. 372.—Wiring Diagram Showing Parts of the Delco Cadillac Eight Cylinder Type Starting, Lighting and Ignition System.

Q. What is the Dyneto-Entz "one unit" system and what advantages are claimed for it?

A. The advantages of the one unit system are said to be simplicity, light weight, low cost and ease of installation, high cranking speed, higher operative efficiency, quiet starting and non-stalling in traffic. It is said by those who favor this system that it is good engineering to simplify any instrument or apparatus when it can be done without sacrificing efficiency or durability. The simplest designs are cheaper to manufacture and are not so apt

to give trouble to the user. The single unit system is much simpler than the two-unit system and it is much easier to install because there is but one machine to set up, drive and wire up. The simplicity of the one-unit system means that there is but one set of bearings to oil, but one pair of brushes (if the device is the single commutator type), one simple and direct connection by silent chain and simple wiring.

The application of the one unit system to the chassis of a White car is shown in the plan view of the chassis at Fig. 373. The motor-generator is attached to a substantial bracket, back of the gear box and is connected to the engine by a driving shaft carrying a sprocket at its forward end just ahead of the shaft supporting bearing, this being in connection with a large sprocket attached to the engine flywheel, as shown at Fig. 374 by a silent chain. The storage battery is carried on the other side of the chassis frame just forward of the rear axle. To start this form of a one unit system a switch is moved from the "off" position to the "start" position and it is left there until one desires to stop. In the White system the control switch is mounted on the steering column as shown at Fig. 374. The Dyneto single unit system has no relays, automatic switches, overrunning clutches, sliding gears or current regulating devices. The usual manner of installation is to drive the motor generator with a silent chain so that the device turns at three times the motor speed. As the tendency is towards small bore, high speed motors, it is necessary that these be cranked over fast as they do not start easily at speeds of rotation below 100 R.P.M. The Dyneto-Entz starter will crank a four cylinder 2¾ inch bore x 4½ inch stroke at 172 R.P.M. on a six volt system drawing 40 amperes. A six cylinder, 3¼ inch bore x 5½ inch stroke is cranked over at 140 R.P.M. on a 12 volt system drawing 35 amperes from the battery. It is said that less energy in watt hours is required of a storage battery at the high cranking speed because while the current output may be a little more, the time that the current is required to flow is much less in securing a positive start than it would be at the lower cranking speed.

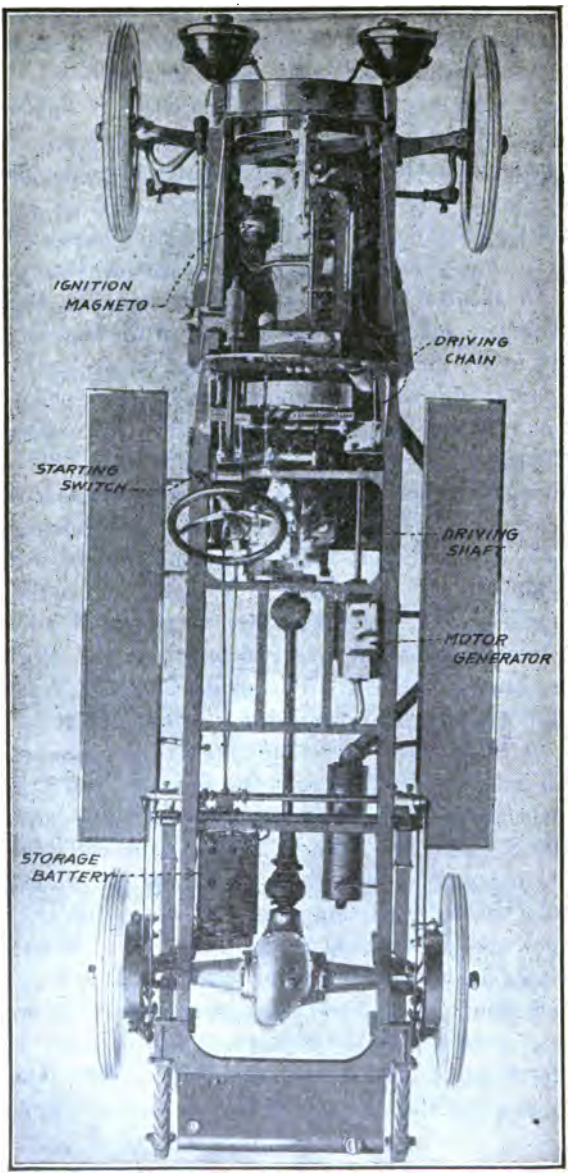


Fig. 373.—Plan View of White Touring Car Chassis Showing Location of Parts of Dyneto One Unit Starting and Lighting System.

Q. Describe the Dyneto "non-stalling" feature.

A. One of the distinctive features of the Dyneto System is that it is non-stalling. This makes driving in traffic perfectly easy without changing gears every time the car is slowed down. This is because when the engine tends to run slower than a certain number of revolutions the device ceases to be a generator and becomes

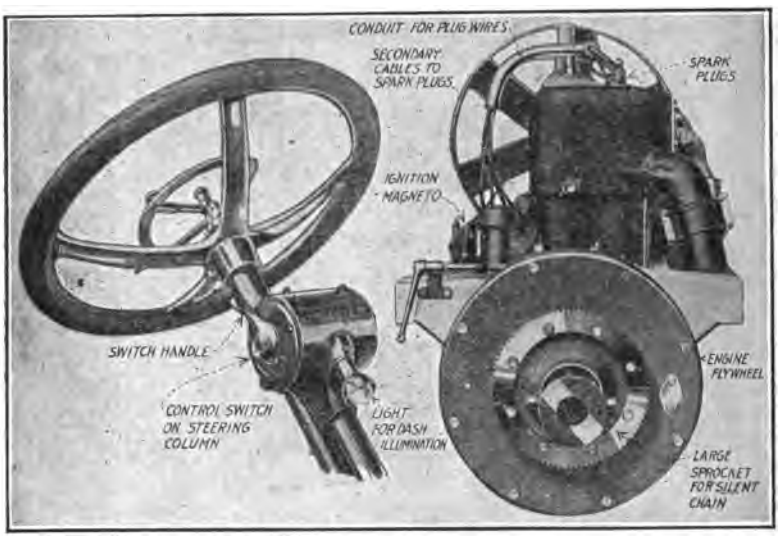


Fig. 374.—View at Left Shows Simple Control Switch of Dyneto-White Starting and Lighting System. Rear View of Motor at Right Shows Large Starting Sprocket Used on White Engine Flywheel.

a motor, automatically drawing current from the storage battery instead of putting current into it. It is contended by those who do not favor the one unit system that the non-stalling feature makes a serious drain on the battery. It is said that no current is drawn from the battery at speeds above 8 M.P.H. and that very little is taken at any lower speed at which the car can be driven. When any current is drawn from the battery back through the motor generator, the series field is strengthened and as this causes an increase of voltage it prevents to a large extent a back

flow of current. The device changes from a motor to a generator at 5 miles per hour,

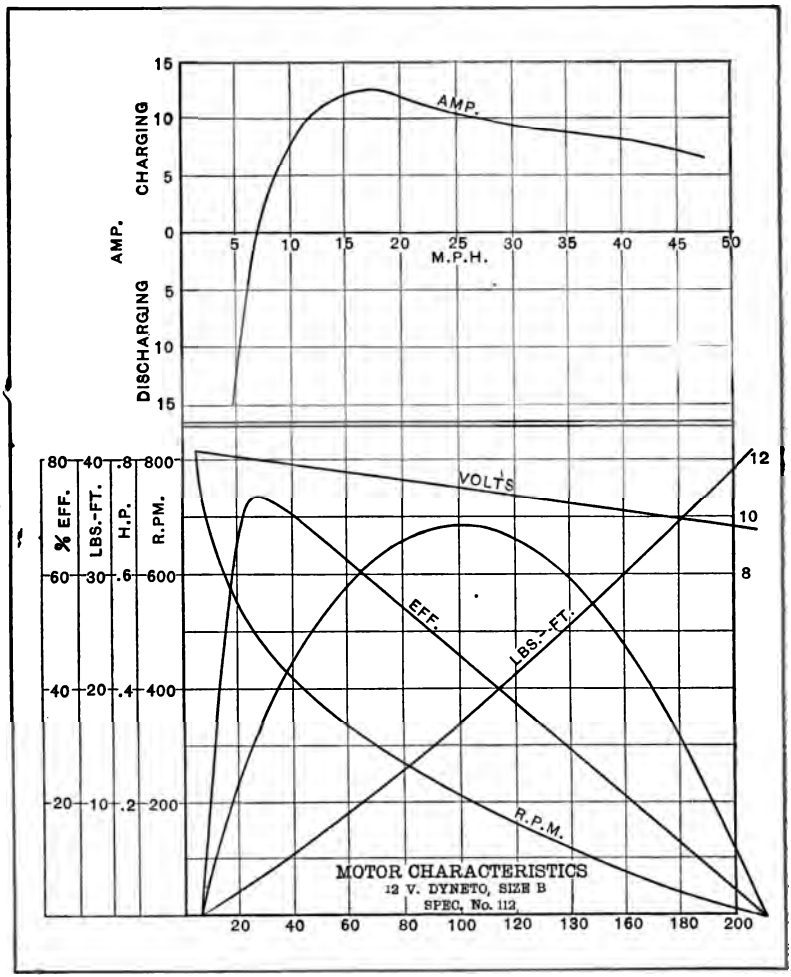


Fig. 375.—Motor Characteristic Curves of 12-Volt Dyneto Machine.

It is necessary to take into consideration the engine to which the machine is to be fitted and proportion the windings accordingly.

It may be desirable on a car having a certain gear ratio to have the back flow occur at a somewhat higher speed than on another car. These factors are taken into consideration in designing the various systems. A number of curves are given at Fig. 375 show-

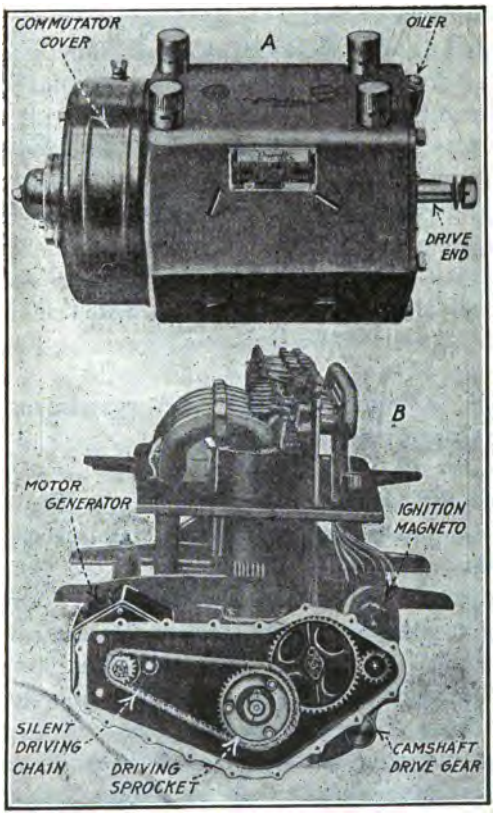


Fig. 376.—The Dyneto One Unit Motor-Generator at A and Latest Method of Installing It on Franklin Engines Shown at B.

ing the motor characteristics of a 12 volt Dyneto size B. It will be observed by consulting the upper diagram that in this case the device changes from a motor to a generator at a speed of 7½ M.P.H. If the speed is increased above this figure the machine

becomes a generator and charges the storage battery. If the speed decreases the device becomes a motor and draws current from the storage battery. It will be observed that the minimum current output of 12½ amperes is produced when the engine is turning over at a speed equivalent to 17½ M.P.H. From this point the current output falls so that at 47½ M.P.H. but six amperes are being generated. At 600 R.P.M. the machine delivers .6 H.P. and is working at 60 per cent. efficiency. Similarly, if used as a generator it is consuming .6 H.P. at 600 R.P.M. At this speed it is capable of exerting the torque of 30 lbs. feet, which means a pull of 30 pounds at a distance of one foot from crankshaft center. Those technically informed will have no trouble in following the motor characteristic curves presented. The reader who is more interested in the practical application of the system than in the technical aspects will not be interested in curves of this nature.

Q. What is the simplest "one unit" system and how is the "motor generator" driven?

A. The complete starting system shown at Fig. 377 is one in which the motor generator replaces the gasoline engine flywheel. This means that it is directly connected to the motor crankshaft and does not employ any reduction gearing of any form. The various members comprising the starting system are indicated in heavy black lines, while the rest of the chassis is shown in light black lines. The system is simple and easily understood. An automatic switch which changes the electric machine into a generator for charging the storage battery when the gasoline engine is running and the starting button is in its released position is one of the important parts. The regulator which makes the rate of charging the battery the same at all engine speeds is placed on the dash. The simple operation of depressing the starting button when the gasoline engine is not turning changes the flywheel generator into an electric motor that draws current from the twenty-four volt storage battery and which rotates the motor crankshaft.

Q. Describe Auto-Lite starting and lighting system.

A. The arrangement of parts of a three unit starting, lighting and ignition system of the Auto-Lite manufacture is shown at Fig. 378, while the various important parts comprising the system are shown in the lower portion of the illustration. As will be apparent, the ignition is from an entirely different source, an independent high tension magneto being provided for this purpose. The generator is placed at the side of the engine and is driven by a silent chain connection from the motor crank shaft. The starting motor is attached to the rear of the engine on the magneto side and is used to turn the engine crank shaft by engaging directly with a gear cut on the outside of the fly-wheel. The system operates on the one wire method. An automatic circuit breaker is provided to which the generator is connected. This is interposed between the generator and storage battery and when the engine speed becomes so low that the generator output is less than the discharge of the battery the circuit breaker interrupts the connection and prevents the battery from discharging through the dynamo. The various circuits are clearly outlined in the diagram and no difficulty should be experienced in tracing the wiring to the various units. The lighting system is very complete, consisting of two head lights, two side lights, a dash light and rear signal. The wires leading to the various units and to the switch are of different colors, so that no trouble will result when tracing the various circuits. In order to prevent damage through short circuiting of a wire, a fuse box is provided, small fuses being interposed in all lamp circuits. When it is desired to start the motor, a switch on the master switch box is operated and a foot pedal depressed. This automatically engages the sliding pinion carried on the motor armature and also closes the starting switch contacts.

The storage battery used with this system is shown at Fig. 378-B. It differs from conventional construction as the three cells are placed end to end instead of side by side, making a long, narrow battery box instead of the type generally used, which is approximately square. The automatic circuit breaker is shown at *C*. The only parts needing inspection are the contact points. The

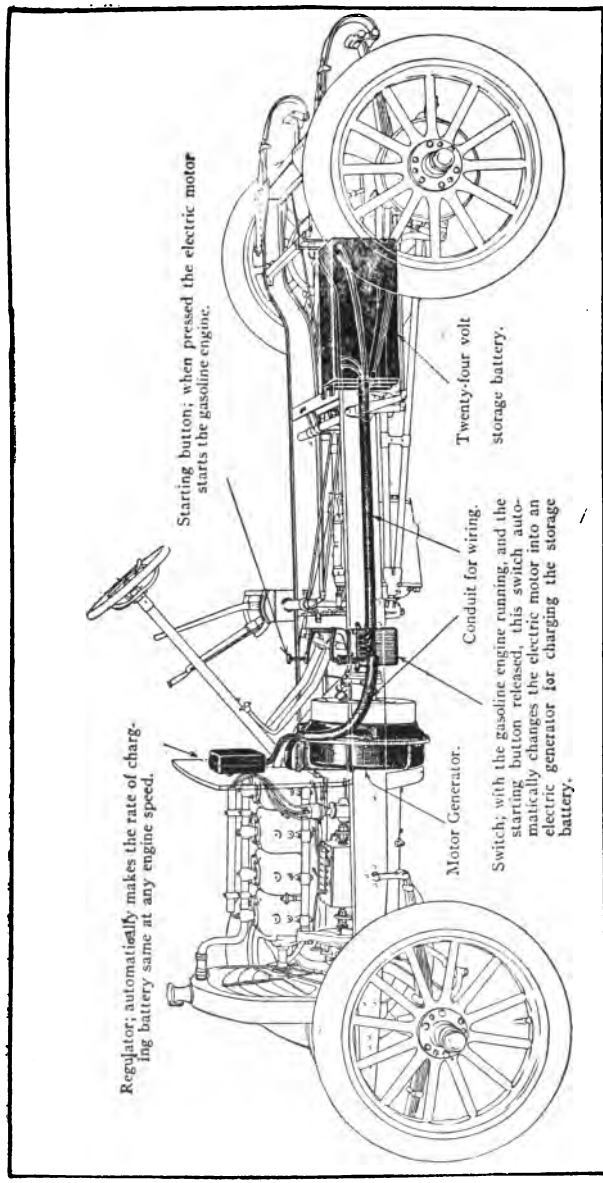

Regulator; automatically makes the rate of charging battery same at any engine speed.
Starting button; when pressed the electric motor starts the gasoline engine.
Motor Generator.
Conduit for wiring.
Switch; with the gasoline engine running, and the starting button released, this switch automatically changes the electric motor into an electric generator for charging the storage battery.
Twenty-four volt storage battery.

Fig. 377.—Electric Starting System Used on Rambler Motor Cars.

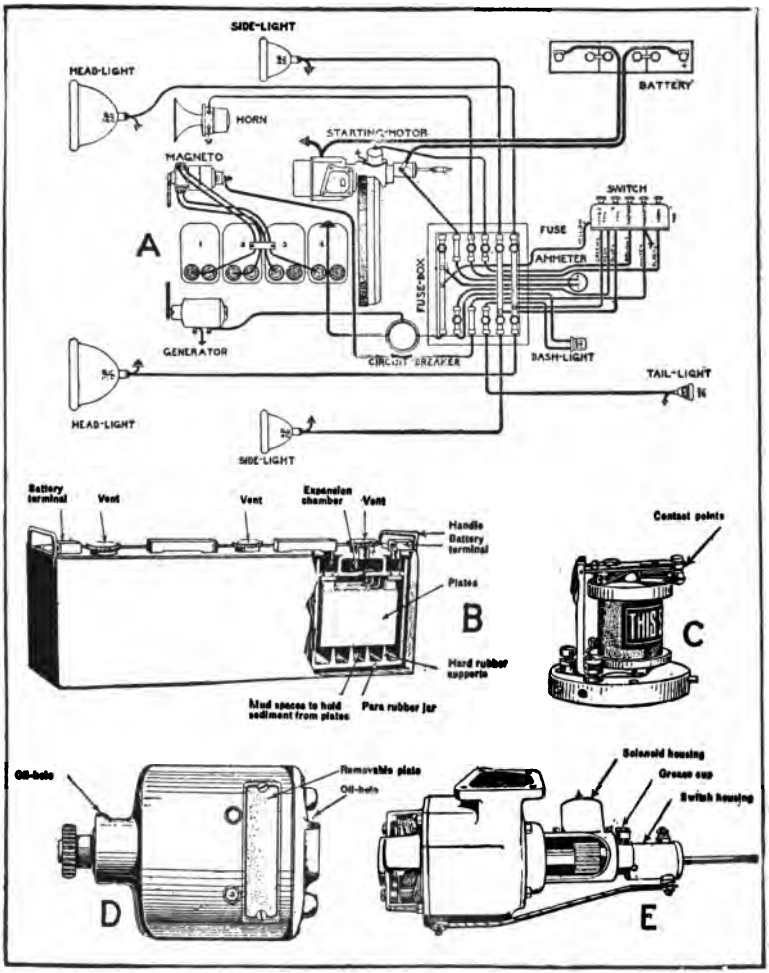


Fig. 378.—Diagram at A Shows Arrangement of Parts of Auto-Lite System and How They are Wired Together. B—Part Sectional View of Storage Battery. C—Automatic Circuit Breaker. D—Current Generator. E—Starting Motor.

generator, which is connected with the crank shaft and driven by a silent chain, is shown at *D*. This has an electric governing system, so that its current output is less at high speeds than it is at normal speeds. The starting motor is shown at *E*, the sliding pinion which engages with the fly-wheel gear being clearly visible through the cut-away portion of the gear enclosing case. The start-

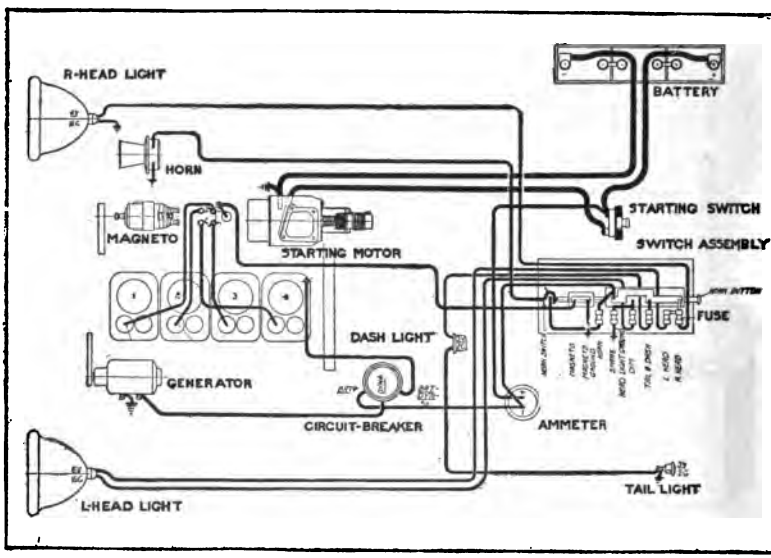


Fig. 379.—Wiring Diagram of 1916 Overland-Auto-Lite System.

ing switch is mounted on the end of the motor and is worked by the same rod that slides the pinion.

Q. How does the 1916 Auto-Lite system differ from the one of the year previous?

A. The diagram Fig. 379 shows the 1916 Overland Auto-Lite system. This differs from the 1915 system principally in the use of an automatic pinion shift, and the units are changed slightly in detail as outlined at Fig. 380, in consequence. The application of the system to the four cylinder power plant is shown at Fig. 381, while the method of installing the units on the six cylinder Overland engine is depicted at Fig. 354.

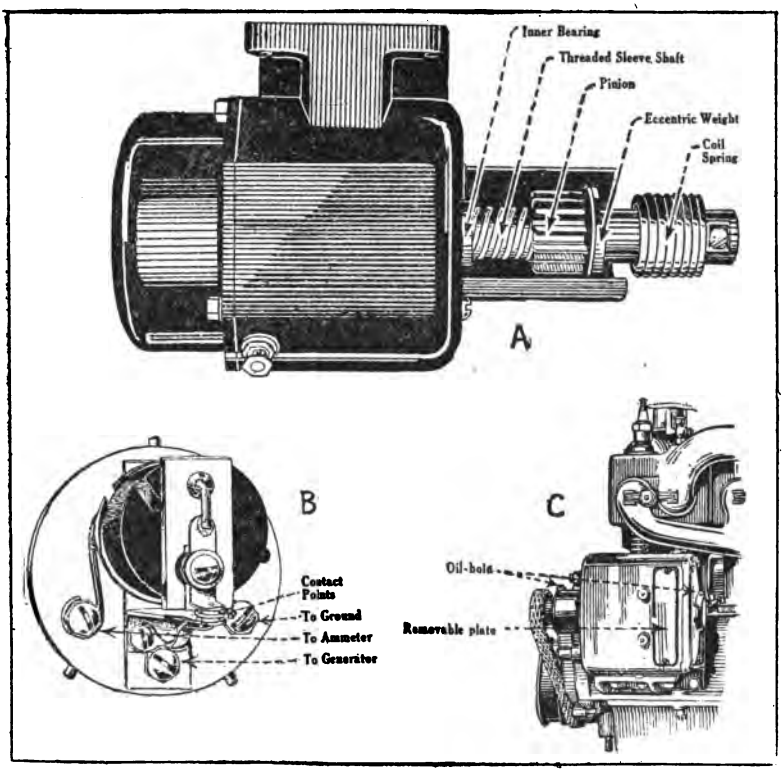


Fig. 380.—Starting Motor Used in 1916 Auto-Lite-Overland System with Automatic Pinion Shift at A. Automatic Cutout Shown at B. Method of Driving Generator with Silent Chain Outlined at C.

Q. How many electric starting and lighting systems have been used?

A. The number of electric systems used are much too numerous to be described in a general treatise of this nature. A complete treatise on all automobile electrical appliances and their use by the same author can be consulted with advantage by those desiring more information. This is "Modern Starting, Lighting and Ignition Systems."

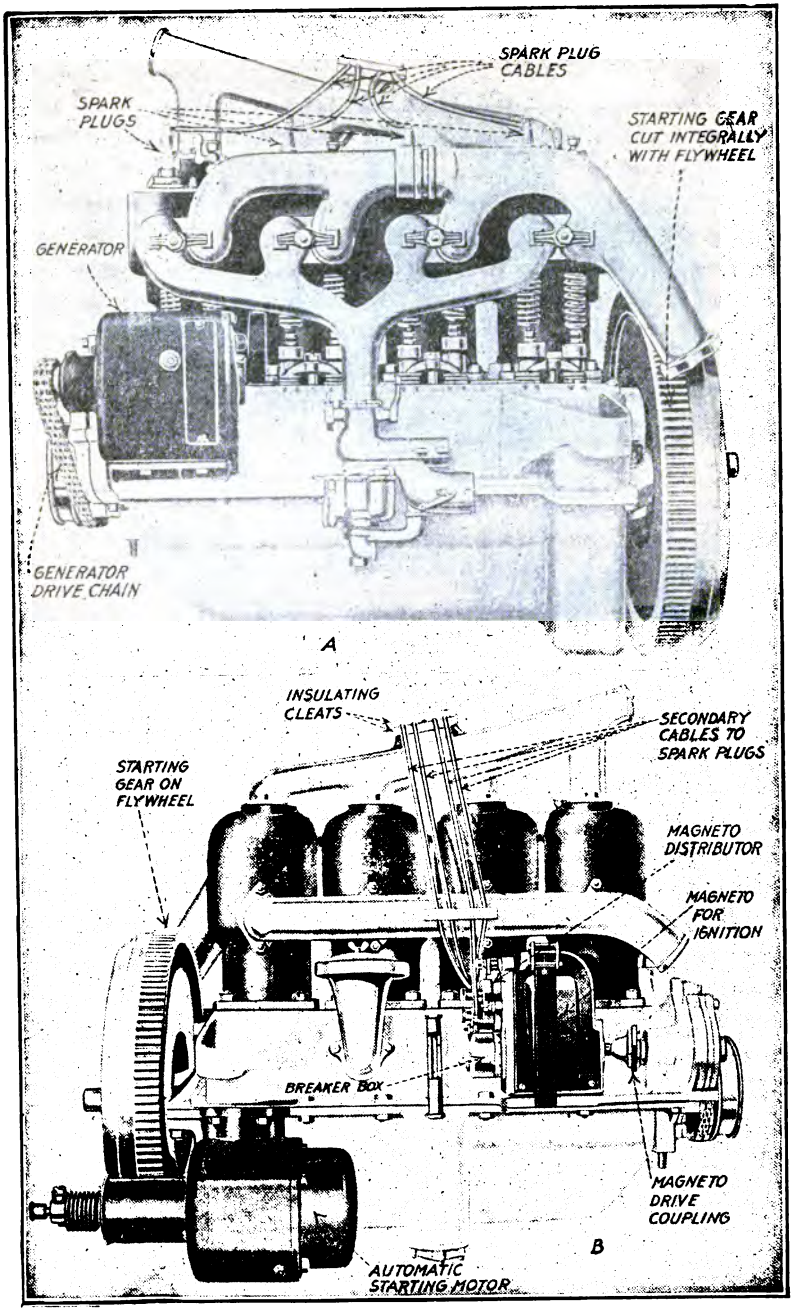


Fig. 381.—Views of Overland Four Cylinder Motor Showing the Application of the Current Generator at A and the Starting Motor and Ignition Magneto at B.

Q. Describe steps to take proper care of the starting system storage battery.

A. The storage battery is made up of several hard rubber cells or containers for the active plates and liquid electrolyte. The whole is surrounded by a wood casing for mechanical protection and ease in handling. Each individual cell is provided with a screw cap for inspection and the addition of electrolyte or distilled water when necessary. The electrolyte must at all times cover the tops of the plates at least one-quarter inch. Insufficient electrolyte will result in warped or buckled plates, and an accumulation of sediment at the bottom of the cells. The battery will be ruined in a short time if the tops of the plates are not kept covered. Each cell must be inspected at least once every week in summer and once every two weeks in winter. All screw caps must be removed and distilled water added to each cell to make up for the natural evaporation. If distilled water cannot be had use clean rain water which has not come in contact with metal or cement.

Never add acid to the cells of the battery. If part or all of the electrolyte has been lost through accidental spilling or leakage get full instructions and advice from the maker. A hydrometer, arranged with a rubber bulb to draw a portion of the electrolyte from each cell, furnishes the best indication of the condition of the battery. The hydrometer shows the specific gravity of the electrolyte, which for a fully charged cell should be 1280 on a specific gravity scale. If the car is out of service for a considerable length of time, as when laid up for the winter, it is necessary to charge the battery at regular intervals. This may be done by running the engine at a car speed of twenty miles per hour for at least one hour every two weeks. If the car is to be stored, and it is not convenient to charge as above, the battery should be removed from the car and placed in a reliable garage to be properly taken care of.

If your battery is arranged with terminal posts for the wiring connections these must be examined occasionally to see that they are clean and free from sulphate. The thorough application of a small amount of vaseline at the metal connections to the battery

posts will prevent sulphating and consequent corrosion and poor electrical contact at these points. If the electrolyte leaks from the joints, bottom, or wood sides of the battery case, one or more of the hard rubber cells are cracked or broken. The battery must be returned to the factory for repairs or replacement. The metal battery box must be thoroughly wiped out with a cloth saturated with ammonia to neutralize the acid and prevent corrosion. The

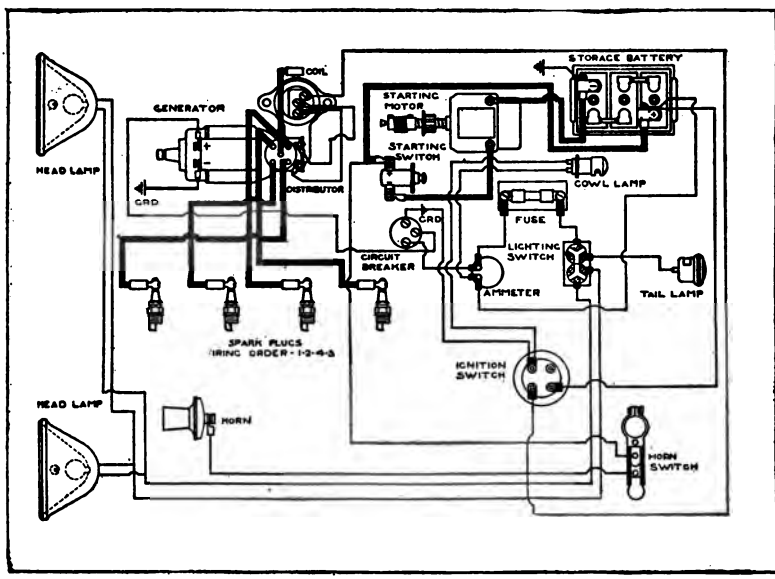


Fig. 382.—Wiring Diagram of Auto-Lite-Chevrolet Starting, Lighting and Ignition System

top of the battery must be kept clean and dry to prevent a leakage of current between the terminals. See that the battery is held securely in its metal box or other container. If necessary pack tightly with waste to prevent the battery shaking about from jolting of the car. Tools, other metal articles, or anything of value should not be placed near the battery as the acid fumes will corrode and destroy metal, cloth and like material. Make certain that the battery terminals cannot touch the cover of the metal battery box. A thin sheet of wood fiber fitted inside the cover of

the battery box will prevent short circuits or grounds from this cause. It must be remembered that the efficiency of any storage battery decreases with drop in temperature and it is only about 50 per cent. efficient at zero temperature. For this reason the demand for current should be kept as low as possible in cold weather and lamps turned off when not needed.

Q. How are electric lamps cleaned and adjusted?

A. To clean head and side lamp reflectors, remove from lamp body and carefully blow out any dust which may have collected on the reflecting surfaces. Then dip a small piece of absorbent cotton in alcohol and lightly wipe over the surface—always from the back to the front. To focus the lamps, open the swinging front of the lamp and direct the light upon some smooth vertical surface at a distance of about ten feet. Loosen the adjusting screw on the slide at the rear of the reflector, and move the bulb and socket out and in until all rings disappear in the illuminated area. Then tighten down the adjusting screw and close the lamp. Any further adjustment of the lamp must be made by bending the arms of the lamp bracket with a heavy wrench until the light from each lamp strikes the road at the point desired.

Q. How can troubles be located in the starting and lighting system?

A. In event of trouble with any lighting system, the makers recommend a careful study of the symptoms, which will usually provide a guide to find the component at fault. The indicator on the dash of most cars shows positively any failure of the generator or any break in the wiring. If the indicator does not indicate "charge" when the engine is speeded up but shows "discharge" when lights are turned on and the engine at rest, the dynamo or current regulator is not working properly. A common trouble is the dynamo brushes not sliding freely in their holders. If the dynamo is driven by friction belt this may be too loose to drive the dynamo at proper speed. If the indicator does not indicate "charge" with the engine speeded up and does not indicate "discharge" with the lights on and the engine at rest, one should look for an open

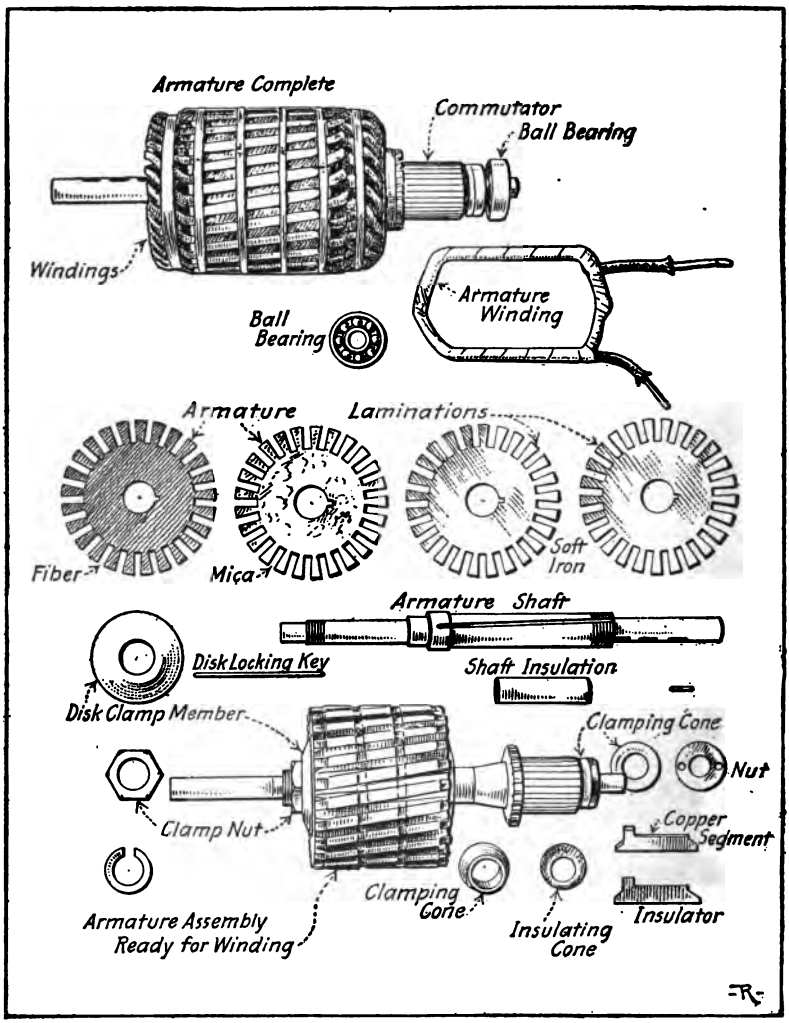


Fig. 383.—Components of North East Motor-Generator Armature Assembly.

circuit or loose connection in the battery wiring or for corrosion or looseness in the storage battery terminals. Sometimes the dynamo terminals may have loosened and imperfect contact exist at this point. Should the indicator show "discharge" with the lights turned off and engine at rest (providing that the indicator pointer is not bent), the insulation on lamp wires may be injured, this permitting contact with the frame, causing a short circuit. If the indicator indicates "charge" with the engine at rest, it is a positive indication that the pointer is bent.

Q. What do low charge indications at ammeter show?

A. If the charge indications are below normal with the engine running, it may be on account of slipping of the driving belt if the dynamo is driven in that manner, or because of poor adjustment of the centrifugal governor, if that type of dynamo is used. If the ammeter "discharge" indications are above normal it is a sign that the lamp load is excessive or one of the lamp wires is in contact with the frame. When the indicator pointer jerks from one reading to another with engine running at constant speed on the discharge scale, it means either a short circuit in the system or a loose terminal.

Q. What does a "blown" fuse indicate?

A. If trouble is experienced from fuses burning out repeatedly, it is a sign that the lamp wires are in contact with the frame at some point or that one of the lamps is defective because of a short circuited filament.

Q. Describe location of starting faults.

A. If the engine cranking speed is very low and this is not due to the engine being stiff, such as would be the case in cold weather or after the engine has been overhauled and bearings tightened, it may be considered a positive indication that the storage battery is almost discharged or that it is defective in some way. If the starting motor does not rotate; the battery may be discharged, the starting switch may not be making good contact or

a motor brush may not make good contact with the commutator. There may be an open circuit in the battery wiring to the motor, or there may be a poor circuit or contact because of corroded battery terminals. If the starting motor rotates but does not crank the engine, it is a sign that the overrunning clutch does not work properly or that the starter pinion is not properly meshed with the flywheel gear.

Q. How are troubles in lighting system located?

A. If the lamps will not light but the starter cranks the engine, this shows that the storage battery is in proper condition and that the trouble is due to burned out or broken lamp filament or defective lamp fuses. If the lamps burn brightly but fail to illuminate the road sufficiently, the bulbs may be out of focus in respect to the parabolic reflector of the lamp or the lamp supporters may be bent in such a way that the rays of light may be directed too far upwards. If the lamps burn dimly or not at all and it is difficult to crank the engine with the starting motor, this means a weak or discharged storage battery. In addition to this, the lamps may be old and have blackened insides, the system might be slightly short circuited, or considerable resistance may be present, due to loose or dirty connections. If the lamps blacken or burn out quickly they are not of the proper quality if they are six volt lamps, and not of the proper voltage if other than six volt lamps. There is one exception to this rule, and that is the bulbs of the tail lamp and dash light, which are three volt lamps when these two are wired together in series. Burning out of the lamps may be caused by the regulator not working properly, and if this is the case the lamps will burn out at high engine speed. If the lamps flicker and the ammeter or indicator needle is unsteady, look for loose connections in the light wires, loose connections between battery and dynamo, loose contact at a lamp connector or lamp bulb, poor contact between fuses and fuse clips, or an exposed wire touching the frame intermittently.

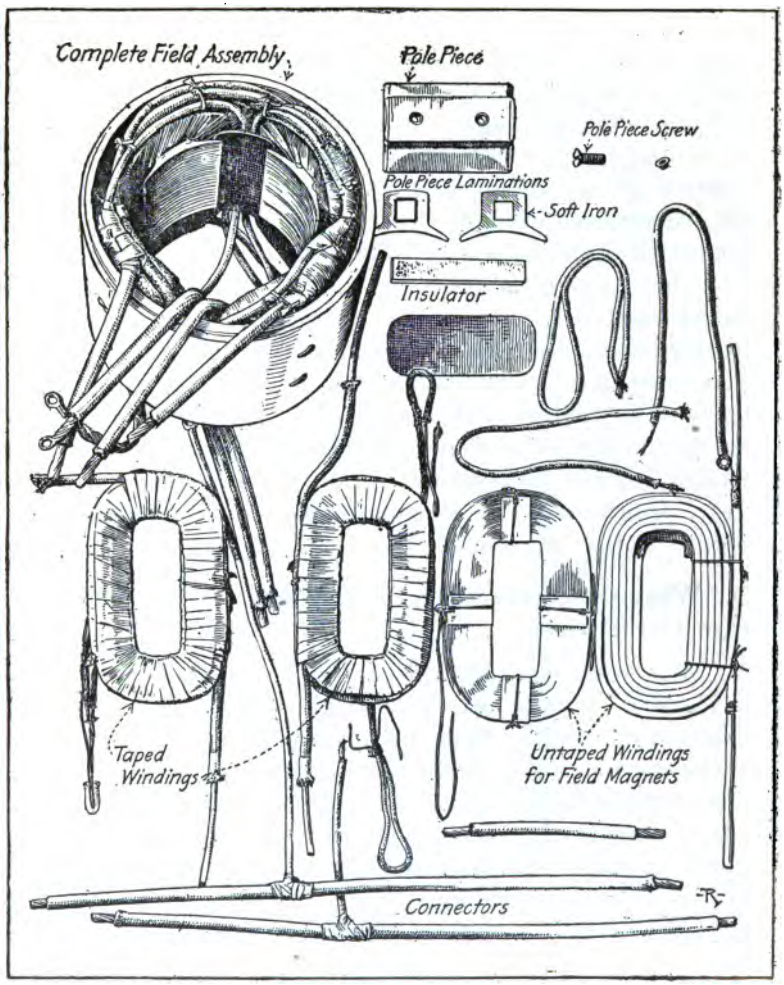


Fig. 384.—Parts of North East Motor-Generator Field Assembly.

Q. What is a test lamp useful for?

A. If one suspects that the battery is discharged, its condition may be readily determined by using a test lamp, which consists of a small lamp of the proper voltage with suitable socket and two

lengths of wire. The test lamp may also be used for locating short circuits or open circuits. It is well to bear in mind that the lead terminals of the battery should be scraped clean and bright at the point where the test lamp wires bear in order to insure a good clean contact. If the test lamp burns brightly it shows that there is current in the storage battery. To locate a short circuit the fuses are removed from the rear of the switch and the wire is disconnected from the negative battery terminal. Connect one of the test lamp terminals to the free battery terminal and touch the other test lamp wire to the frame of the car. The test lamp should light if good contact is made, this indicating that the positive battery terminal is properly connected to the ground. Keep one test lamp wire in contact with the negative terminal and touch the other wire to the end of the battery wire just disconnected. If the test lamp lights it shows that a conductor or wire connected to the battery, lamps, horn or starting motor is in contact with or grounded to the frame of the car.

Q. What should the wiring be examined for and what care is needed of the wires?

A. Any wires having injured insulation should be wrapped with electrical tape to prevent metallic contact between the conductor and the frame. Open circuits are best indicated by feeling of the wires where they fasten to the terminals to make sure that positive contact is made and that the terminal binding nuts are not loose. Short circuits may also be located if no test lamp is available by following the various wires, and if any of these are found in contact with the frame it is a wise precaution to pull them away and to wrap the section that was in contact with the frame thoroughly with insulating tape. If one lamp flickers and the rest burn brightly, look for a poor connection between the lamp and the lamp connector, a loose terminal at the junction switch or a defective fuse. If all lamps flicker, look for loose connections in wiring between battery and junction switch. When lamp bulbs have been renewed in head lights it is sometimes necessary to refocus the lamps. Head lights should not exceed 15 candle power, and should always be of the high efficiency filament type. Cheap

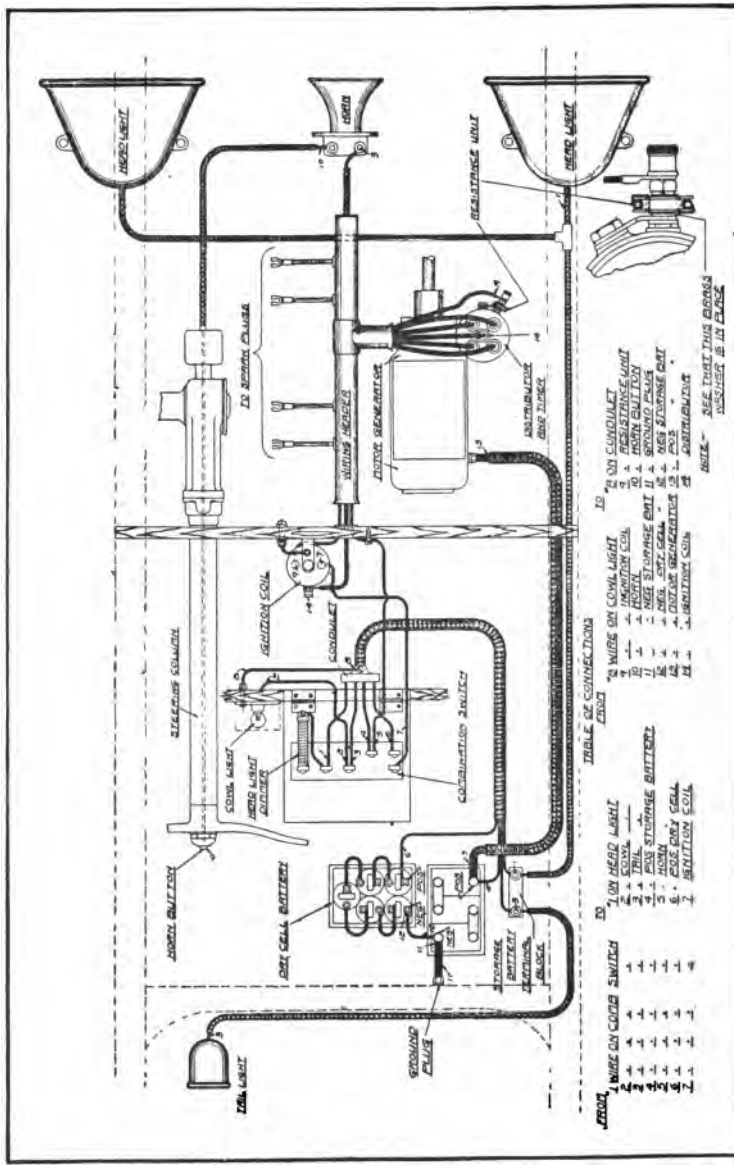


Fig. 385.—Non-Technical Wiring Diagram of Delco-Olds Starting, Lighting and Ignition System.

carbon filament lamps will not only consume undue current but will not prove enduring. Tungsten filament lamps are best.

Q. What faults can be looked for in motors and generators?

A. While every effort has been made by the manufacturers of electric starting and lighting systems to have the various units function as nearly automatically as possible, it will be evident that some attention will be needed by the various units. The generator should be looked over from time to time and should any carbon dust be worn from the brushes by the commutator and deposited in the lower part of the casing it should be blown out with compressed air. It is stated that an accumulation of this dust may result in a ground to the generator case or produce a short circuit between the brush carrier and case. If the commutator is blackened or rough it must be smoothed down with fine sandpaper while the armature is rotating. Never use emery cloth for this purpose. After smoothing down the commutator remove all particles of metal which may bridge across between the copper segments. The insulating material between the commutator segments should not be higher than the surfaces of the segment, and if any of it projects it must be filed down slightly lower than the copper pieces by using a small file.

The brushes are the part of the generator that demand the most attention and to which most of the troubles in devices of this kind are due. They should be examined to see that they are in perfect contact with the commutator and that they do not stick in the brush holders. Any dirt or grease on the brush assembly should be removed. One of the most fertile causes of poor brush contact with the commutator is on account of insufficient spring tension. When examining the brushes care should be taken to see that these are maintained positively in contact with the copper segments. Care should be taken not to have the spring pressure too great, as this would produce rapid depreciation of the brushes and heating of the commutator. Brushes that have worn down till they are short must be replaced with new ones. When replacing brushes be sure that they fit the commutator surface exactly over the whole area of the end of the brush, and in all cases use brushes for replacement

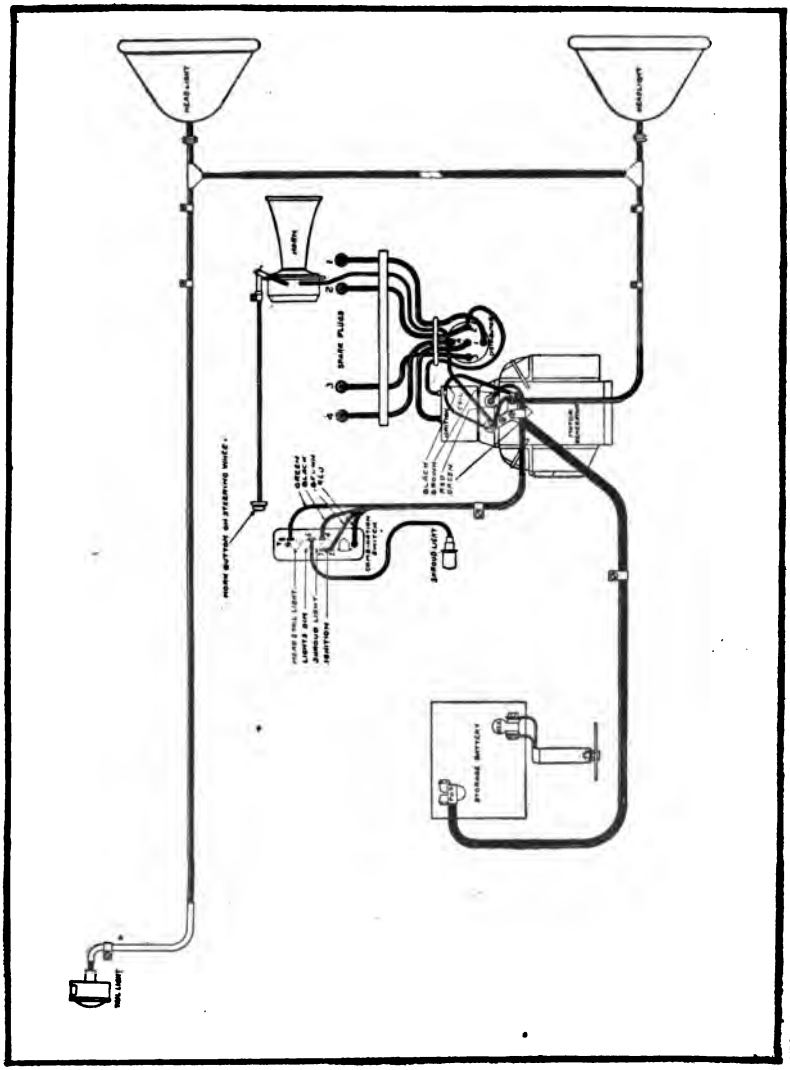


Fig. 386.—Delco Starting, Lighting and Ignition System Used on 1916 Four Cylinder Oakland Automobiles.

furnished by the maker of the generator. In some generators, shunt connections, which are called "pigtails," are used for connecting the brushes. If the new brushes furnished by the factory have these connections attached care should be taken to make the connection exactly the same as on the old brushes.

It is imperative that the commutator be kept clean, as any oil or grease on the segments will collect carbon dust and produce short circuiting. The brush holders should be entirely insulated from the carrying case, and if any of the insulating bushings, washers or plates are found defective they must be replaced with new ones.

Q. What points do makers of starting systems wish the car operator to bear in mind?

A. The user of any electrical starting and lighting system will avoid trouble and expense by the observation of the following instructions:

Don't replace worn-out brushes with any others than those supplied by the manufacturer.

Don't put oil or grease on the commutator of the generator or motor. No lubrication is wanted there.

Don't turn the hose on the generator or motor when washing your car.

Don't tighten up on the silent chain drive unless the slack becomes excessive from stretching. The chain must be run with a reasonable amount of slack to prevent noise and wear.

Don't fail to lubricate the silent chain drive at frequent intervals. Noise will be eliminated and wear reduced. Keep the chain and sprockets clean, and free from dirt and gravel.

Don't try to run the car with the starting motor as this will seriously injure the battery.

Don't make any adjustments without knowing what the result will be.

Don't take anything apart unless you are sure you can put it back together again.

Do not connect additional apparatus, such as electrical horns, cigar lighters, etc., to the system without taking the matter up

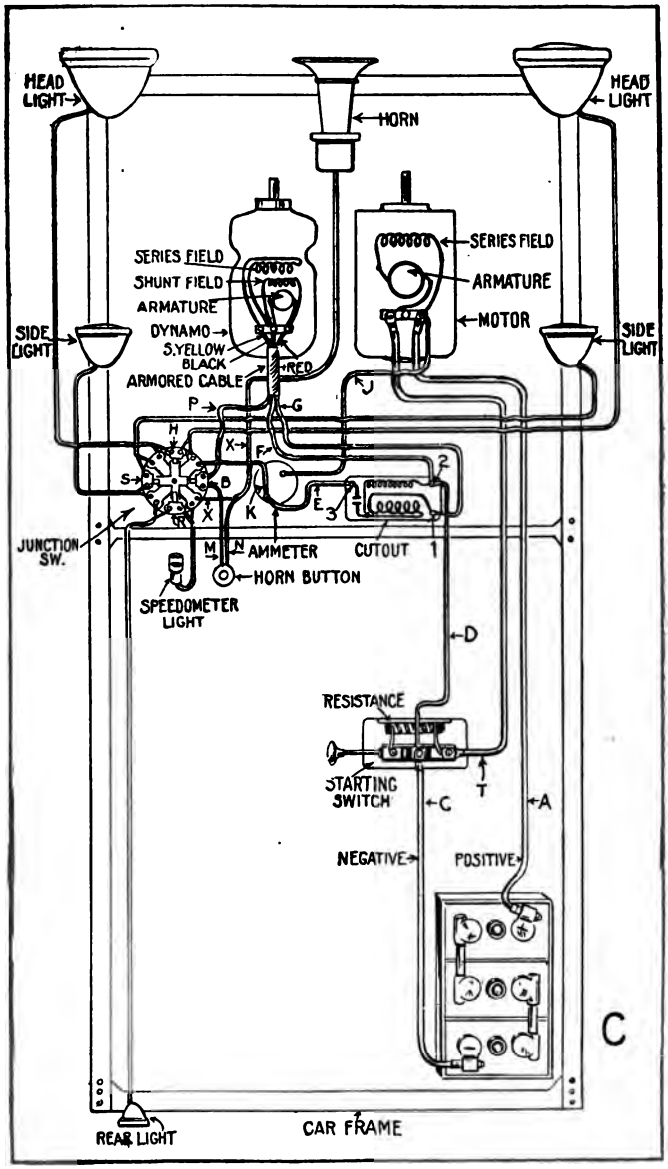


Fig. 387.—Non-Technical Wiring Diagram Showing Arrangement of Parts of Gray & Davis Two Unit, Two Wire Starting and Lighting System, Utilizing Centrifugally Governed Generator.

with the factory. The surplus capacity of the system is large, but there is a limit to the amount of current which the generator can produce. Use the same judgment and reason in the operation of the electric lights on a car as you do those in your home or garage. When a car is running it is not necessary to burn all the lights, the two head and the tail are all that are required or that are of any service. When the car is standing at night, use the side and tail lights only. When push type connectors are used, if halves of connectors are loose when pushed together, the contact will be poor. Spread the connector posts slightly so that they will slide in their sockets snugly. If Ediswan type are used, and plunger springs in connector do not operate, replace the connector with a perfect one.

LESSON THIRTY-NINE

USEFUL INFORMATION FOR MOTORISTS.

WINTER DRIVING

(Courtesy of Willys-Overland Co., Toledo, Ohio.)

Tire Chains.—For driving in winter, or on slippery roads, the use of tire chains is advisable. The chains should be properly adjusted. When they are applied too tightly they will cut the tread and render it useless in a short time. Adjust the chains so that they will shift around over the tread, to distribute the wear.

In an emergency, as when the car has become mired, or the road is so slippery that the wheels cannot secure sufficient hold to move the car, a rope wound around the rear wheel in between the spokes will be found a simple and effective means of getting started.

Non-freezing Cooling Solutions.—Whenever the temperature approaches 40 degrees Fahrenheit above zero, the cooling system should be made frost-proof by mixing a non-freezing substance with the water. Wood alcohol or denatured alcohol is best for that purpose.

The following table may be used in estimating the quantity of alcohol required for different temperatures:

Model 69—Capacity of Cooling System 4¾ Gallons.

4 pints alcohol added to the water will not freeze at 10 degrees Fahrenheit above zero.

7½ pints alcohol added to the water will not freeze at 5 degrees Fahrenheit above zero.

9½ pints alcohol added to the water will not freeze at zero Fahrenheit.

15 pints alcohol added to the water will not freeze at 25 degrees Fahrenheit below zero.

Model 71—Capacity of Cooling System 6 Gallons.

4¾ pints alcohol added to the water will not freeze at 10 degrees Fahrenheit above zero.

9½ pints alcohol added to the water will not freeze at 5 degrees Fahrenheit above zero.

12 pints alcohol added to the water will not freeze at zero Fahrenheit.

19 pints alcohol added to the water will not freeze at 25 degrees Fahrenheit below zero.

Since alcohol evaporates more quickly than the water, any loss should be replaced with equal parts of alcohol and water.

The use of powerful chemicals like calcium chloride, sodium chloride, or of glycerine in cooling solutions is apt to have troublesome consequences, because the chlorides attack the metal of the system, while glycerine will act as a solvent of the rubber connections and is troublesome in other ways.

CALCIUM CHLORIDE SOLUTIONS

2 pounds salt, 1 gallon water	Freezing point,	18°	F.
3 pounds salt, 1 gallon water	Freezing point,	1.5°	F.
4 pounds salt, 1 gallon water	Freezing point,	−17°	F.
5 pounds salt, 1 gallon water	Freezing point,	−39°	F.

WATER AND ALCOHOL SOLUTIONS

Water 95%, Alcohol 5%	Freezing point,	25°	F.
Water 85%, Alcohol 15%	Freezing point,	11°	F.
Water 80%, Alcohol 20%	Freezing point,	5°	F.
Water 70%, Alcohol 30%	Freezing point,	−5°	F.
Water 65%, Alcohol 35%	Freezing point,	−16°	F.

WATER, ALCOHOL AND GLYCERINE SOLUTIONS

Water 85%, Alcohol—Glycerine 15%	Freezing point,	20°	F.
Water 75%, Alcohol—Glycerine 25%	Freezing point,	8°	F.
Water 70%, Alcohol—Glycerine 30%	Freezing point,	−5°	F.
Water 60%, Alcohol—Glycerine 40%	Freezing point,	−23°	F.

Alcohol and Glycerine—equal proportions.

The Best Mixture.—Plain water and alcohol solutions would be the best were it not for the ease with which such compounds boil and the rapidity with which they evaporate. We have seen that the objections advanced against calcium chloride solution have ample foundation and that such compounds are not suitable for use, the chief advantage, that of cheapness, having been eliminated by the reduction in the price of denatured alcohol. The addition of a little glycerine to an alcohol and water solution reduces liability of evaporation, and when used in such quantities it has no injurious effect to speak of on rubber hose.

If the cooling water should freeze through neglect of ordinary precautions, do not attempt to thaw it out by starting the motor, but thaw it by putting the car in a warm place.

During cold weather the motor is sometimes hard to start after the cylinders have become thoroughly chilled. The remedy in a case of this kind is to introduce a small quantity of gasoline—about a teaspoonful—through the priming cocks direct into the cylinder. The rich mixture secured in this way will start the motor. Once started the clyinders will warm up and continue to work without trouble. In most cases the closing of the air-shutter in the carburetor will be sufficient to secure a start.

It is always well, when making a stop, to cover hood and radiator, which will give considerable protection from the likelihood of freezing and also make a new start easier.

A cloth wrung out in very hot water and held around the carburetor also will facilitate starting in extremely cold weather. This may become necessary in extremely low temperatures, when water which may have entered the float chamber of the carburetor and separated from the gasoline is likely to freeze and clog up the spray nozzle.

Cold Weather Lubrication.—The oiling system deserves some attention during the winter. Do not use too thick a lubricant, for the cold will congeal it still more. When starting in cold weather run the motor slowly for a short time, until things are warmed up sufficiently for the oil to flow freely.

Body Polish.—A much recommended body polish is made by mixing the following ingredients:

Turpentine	1 gallon
Paraffine Oil	1 pint
Oil of Citronella	3½ ounces
Oil of Cedar	1½ ounces

Another scheme is to use a mixture of boiled linseed oil and turpentine, applying it sparingly and rubbing absolutely dry. The use of these polishes will restore even an old car to a degree of brightness that will please the owner. Floor wax is also used, as is furniture polish.

Care of Tops.—Mohair tops should be frequently dusted and brushed off. Pantasote tops and curtains are best cleaned with a soft brush dipped in water to which a little ammonia has been added. Afterwards rub dry. Never attempt to clean top and curtains with gasoline or kerosene. Do not fold the top until it has become thoroughly dry, because any moisture remaining in the folds is apt to cause mildew, besides making the top leaky and unsightly with spots. When a car is not used for some time, it is best to open the top, which keeps it well stretched and smooth.

Care of Leather Upholstery.—Do not use gasoline in cleaning leather upholstery. Plain water with a little ammonia will remove the dirt and a brisk rubbing with a clean woolen or flannel cloth will do the rest. For still more careful treatment use a regular leather dressing.

Care of Cloth Upholstery.—Do not use an acid solution in cleaning cloth upholstery.

Cloth is not affected by climatic conditions and withstands both heat and cold, and having no oil in its make-up, does not pick up or hold dust readily. To remove ordinary dust, beat cushions and backs lightly with stick or carpet beater, then remove dust with whisk-broom or brush. Grease or oil may be removed by the application of a solution of lukewarm water and Ivory soap applied with a woolen cloth.

INDEX

A.

Accessories, Useful 565
Acid, Effect of in Oil 213
Acid, How to Determine in Oil 213
Action of Centrifugal Pumps . 245
Action of Differential Gear ... 323
Action of Friction Drive Axle . 280
Action of Gear Pump 245
Action of Induction Coil 158
Action of Progressive Gearset . 293
Action of Typical Dynamo ... 176
Adjusting Brakes 541
Adjusting Simple Carburetors. 131
Adulterants, How to Detect in Oil 216
Advantages of Electric Ignition 144
Advantages of Eight and Twelve Cylinder Motors ... 586
Advantages of Gear Drive 313
Advantages of Magneto Ignition 177
Advantages of Selective Gearset 297
Air Circulating Fan Drives ... 255
Air Circulating Fans 254
Air Circulating Through Radiator 252
Air Cooling, Advantages of .. 238
Air Cooling by Blower Draft . 238
Air Cooling by Convection and Radiation 234
Air Cooling by Flywheel Suction 237
Air Cooling by Radiation 234
Air Cooling by Simple Radiating System 234
Air Cooling, Defects of 238
Air Cooling Methods 234
Air Currents, How Produced . 236
Air Gap of Spark Plugs 154
Airless Tires 387
Air Resistance, Effect of 33
Air Starting System 620
Air Stove, Use of 600
Alcohol-Acetylene Process 111
Alcohol as Fuel 110
All Spur Planetary Gear 281
Angle of Clutch Cone Taper .. 259
Angular Loads 407
Anti-freezing Solutions 684
Anti-friction Bearings, Installing 419
Anti-friction Bearings, Types of 404
Armature, How Wound 179
Armored Wood Frame 342
Artillery Wheel 367
Assembling Ball Bearings 421
Auto-Lite System 666
Automatic Pinion Shift 642
Automatic Speed Governor ... 431
Automatic Type Carburetor .. 127
Automobile Bodies, How Made 33
Automobile Bodies, Torpedo and Streamline 33
Automobile Brakes 448
Automobile, Definition of 17
Automobile, Essential Elements of 23
Automobile Lubricants 212
Automobile Parts, Functions of 30
Automobile Parts, How Lubricated 217
Automobile Power Plant, Fuels for 105

Automobile Power Plant, Function of 23
Automobile Power Plant, How to Start 425
Automobile Power Plants, Multiple 49, 593
Automobile Power Plant, Parts of 27
Automobile, Principal Types of 17
Automobile, Principal Body Types 32
Automobile Warning Signals . 570
Automobile Wheels 367
Automobiles, Classes of 21
Automobiles, Electric 18
Automobiles, Gas Power for .. 18
Automobiles, How They Differ 21
Automobiles, Power Needed for 35
Automobiles, Steam Power for 17
Auxiliary Air, Value of 128
Axle, Combined Dead and Live 334
Axle, Double Reduction 335
Axle, Friction Drive 280
Axle, Front 363
Axle, Full-floating 332
Axle, Functions of Rear 329
Axle, Live Types 332
Axle, Semi-floating 332
Axle, Two-speed Direct Drive . 337
Axle, Types of Rear 329
Axles, One Piece for Steering . 356
Axles, Types of 363

B.

Back Lash in Steering Gears .. 537
Ball Bearing, Assembling 421
Ball Bearings 407
Ball Bearings, Lubricant for .. 423
Ball Thrust Bearing for Clutch 261
Band Type Clutch 271
Battery—Magneto Systems ... 187
Battery, Primary 164
Battery, Secondary 165
Bearing, Take Down 414
Bearings, Adjustment of 88
Bearing, Anti-friction 400
Bearings, Ball 407
Bearings, Die Cast 402
Bearings, Fitting to Shaft 402
Bearings for Conecting Rods . 87
Bearings, Friction of 412
Bearings, How Used 400
Bearings, Load Imposed on .. 407
Bearings, Plain 400
Bearings, Roller 404
Bearings, Scraping-in 403
Bearings, Separators for 414
Bearings, Soft Metal 401
Benzol as Fuel 109
Bevel Differential Gear 323
Black Smoke at Exhaust, What it Indicates 131
Block Castings, Cylinders for . 58
Blowouts, Causes of 550
Blowouts, Permanent Repair .. 555
Blowouts, Temporary Repair . 554
Body Designs, Recent 602
Body Polish 686
Bolted on Rims 379
Bore, Relation to Stroke 89
Brake and Clutch Interlock ... 455
Brake Drums, How Made 453
Brake, Hydraulic 606
Brake Location, External 452
Brake Location, Internal 452
Brake Shoes 453
Brake, Use of Engine as 464
Brakes, Adjustment of 541
Brakes for Automobiles 448
Brakes, Cork Inserts In 453
Brakes for Countershaft 450
Brakes, How Operated 455
Brakes, Materials Used in 453
Brakes, Troubles with 541
Brakes, Where Applied 449
Built-up Crankshafts 91
Bumping, Cause of 492

C.
Cambered Side Members 343
Camshaft, Function of 77
Camshaft, Method of Drive ... 78
Cams, How They Raise Valves 79
Cams Inlet and Exhaust 78
Cantilever Spring 602
Capacity of Storage Battery .. 171
Carbon Deposits, Formation of 502
Carbon Deposits, Removal of . 502
Carburetion, Definition of 116
Carburetor, Automatic Type .. 127
Carburetor, Auxiliary Air for . 128
Carburetor, Bubbling Type ... 120
Carburetor, Concentric 124
Carburetor, Float-feed 122
Carburetor, Multiple Jet 129
Carburetor, Simple Mixing Valve Type 121
Carburetor Spraying Type ... 121
Carburetor, Surface Type 120
Carburetor Troubles 512
Carburetor, Venturi Tube Type 126
Carburetor, Wick Type 120
Carburetors, How Adjusted .. 131
Carburetors, Simplest Form of 120
Care of Chains and Sprockets 531
Care of Tops 686
Care of Upholstery 686
Carrying Tools, Clothing, etc. . 579
Caster Front Axle Construction 366
Cast Steel Wheel 368
Causes of Lost Power 494
Causes of Sudden Car Stop .. 487
Central Location of Control Levers 456
Centrifugal Pump, Action of . 245
Chain Drive, Enclosed Type .. 312
Chain Pitch, Definition of 310
Chains and Sprockets, Care of 531
Change Speed Gear for Four Wheel Drive 314
Change Speed Gearing, Four Speed 299
Change Speed Gearing, Friction Type 274
Change Speed Gearing, How Placed 301
Change Speed Gearing, Individual Clutch 287
Change Speed Gearing, Planetary 281
Change Speed Gearing, Progressive Sliding Gear 293
Change Speed Gearing, Selective Type 295
Change Speed Gearing, Sliding Type 291
Change Speed Gearing, Unit with Motor 303
Change Speed Gearing, Why Needed 272
Charging Storage Batteries ... 173
Chassis Design for 1916 602
Circuits, Open and Closed 148
Climbing a Grade 462
Clincher Rim 377
Clutch Action, Principle of .. 257
Clutch and Brake Interlock .. 455
Clutch, Band Type 271
Clutch, Cone Type 258
Clutch, Five Plate Type 266
Clutch, Friction Disc Action .. 274
Clutch, Function of Ball Thrust Bearing 261
Clutch, Hele-Shaw Design ... 268
Clutch, Inverted Cone 258
Clutch Lubrication 471
Clutch Materials, Friction of . 260
Clutch, Multiple Disc Type ... 267
Clutch, Overrunning 440
Clutch Pedal, Function of 440
Clutch, Requirements of 271
Clutch, Three Plate Type 263
Clutch Troubles 521
Clutch Trouble, Cone Does Not Release 523
Clutch Trouble, Failure to Drive 522

Clutch Trouble, Harsh Engagement 521
Clutch Trouble, Multiple Disc 524
Clutch Trouble, Preventing Spinning 524
Clutch Trouble, Slipping 521
Clutch Trouble, Weak Spring . 523
Clutch, Why Used 256
Coefficient of Friction, Definition of 260
Coefficients of Friction of Materials 260
Cold Test of Oil 215
Cold Weather Lubrication ... 685
Color or Exhaust Gases 133
Combination Battery-Magneto Systems 187
Combustion, Air Needed for .. 116
Combustion, External 38
Combustion, Internal 38
Combustion, What It Is 114
Common Method of Water Cooling 240
Commutator or Timer Defects 505
Complete Outfit for Care of Tires 545
Compound Springs 350
Compression, How to Test ... 494
Compression, Value of 38
Concentric Float Carburetor .. 124
Condenser for Induction Coil . 157
Cone, Angle of Taper 259
Cone Brake, Application of .. 263
Cone Clutch 258
Cone Clutch, Advantages of .. 261
Cone Clutch, Disadvantages of 261
Cone Clutch, Inverted 258
Cone Clutch, Preventing Spinning 262
Cone, Materials to Face 260
Connecting Rod Bearings 87
Connecting Rod, Forms of ... 87
Connecting Rod, Function of . 86
Connecting Rod, Length of .. 86
Connecting Rod, Materials Used in 86
Constant Level Splash System 221
Construction of Differential Gear 323
Construction of Dry Battery .. 165
Construction of Pneumatic Tires 390
Construction of Storage Battery 169
Control Levers, Stiff Action of 540
Controlling Engine Speed 430
Controlling Planetary Gearset 433
Cooling Flanges, How Applied 236
Cooling Methods, Possible ... 231
Cooling, Simplest Method of .. 231
Cooling Systems, Heat Loss in 233
Countershaft Brakes 450
Counter Weights, Where Used 91
Crankcase, Barrel Type 95
Crankcase, Forms of 95
Crankcase, Function of 95
Crankcase Materials 95
Crankcase, Two Piece 96
Crankpins, Spacing of 92
Crankshaft, Built up 91
Crankshaft, Functions of 90
Crankshafts, How Made 90
Crankshafts, Number of Main Bearings 94
Cylinder Head, Methods of Constructing 58
Cylinder, Hottest Portion of .. 231
Cylinder, L Head 60
Cylinder Oil, Specifications of . 217
Cylinder, Relation of Bore to Stroke 89
Cylinder, T Head 60
Cylinder, Valve Chambers for 56
Cylinder, Water Jackets for .. 56
Cylinders, Block Castings 58
Cylinders for Gas Engines ... 54
Cylinders, Individual 58
Current Consumption of Induction Coil 163

Cushion Tires 386
Cut-out Valve for Muffler 140

D.

Defects of Valve Systems 503
Definition of Automobile 17
Definition of Coefficient of Friction 260
Definition of Internal Combustion 38
Delco System 646
Delco System Operation 650
Demountable Rim 379
Design of Manifold 100
Detachable Artillery Wheel .. 375
Detchable Wheel, Rambler ... 375
Detachable Wire Wheel 373
Detecting Missing Cylinders .. 508
Die Cast Bearings 402
Diesel System 118
Differential Gear, Action of .. 323
Differential Gear, Bevel Type 323
Differential Gear, Construction 323
Differential Gear, Forms of ... 323
Differential Gear Lock 328
Differential Gear, Spur Type . 323
Differential Gear, Why Needed 321
Differential Gearing, Trouble With 533
Differential Gearing, Worm .. 607
Differential Piston, Two-cycle Engine 45
Discharge Rate, Meaning of .. 173
Distributor Ingnition System . 197
Double Ignition Systems 203
Double Reduction Axle 335
Double Reduction Chain Drive 308
Double Reduction Drive System 308
Double Reduction Gear Drive 310
Drag Link, Use of 357
Drive Chains, Silent Type ... 312
Drive Gearing, Types of 304
Driving Chains, Block or Roller 311
Driving Chains, Forms of 310
Driving Gears, Defects of 532
Driving Hints 460
Dry Batteries, How Measured. 162
Dry Battery Construction 165
Dry Cells, Sizes of 169
Dynamo and Magneto Compared 175
Dynamo Drives 187
Dyneto-Entz System 656

E.

Efficiency of Power Transmission Systems 313
Electrical Ignition 143
Electrical Units 161
Electricity, How Measured ... 161
Electricity, Methods of Producing 164
Electric Automobile, Features of 18
Electric Gearshift, Advantages of 446
Electric Lighting, Methods of 568
Electric Motor Starters 624
Emergency Oil Supply to Crankcase 230
Emergency Stop 458
Engine Control Levers, Where Placed 363
Engine, How to Prime 420
Engine, Eight Cylinder 593
Engine, Twelve Cylinder 590
Engine Lubricants 465
Engine Starters 619
Engine Speed Control 430
Equipment of Motor Cars Regular 565
Erratic Steering, Cause of ... 492
Essential Elements of Automobiles 23
Excess Air in Mixtures, How Indicated 132
Exhaust Gas, Color of 133
Exhaust Gas Muffler 139

Exhaust Stroke, Actual Duration of 71
Exploding Gas in Cylinder ... 141
External Brakes 452
External Combustion, Definition of 38

F.

Fan Bearings, How Oiled ... 469
Faults of Spark Plug 506
Filing Cuts in Casings 557
Fire and Flash Tests of Oil .. 214
Five Plate Clutch, Construction of 266
Floating Battery on the Line . 188
Float Feed Carburetor 122
Float Bowl Defects 515
Flywheel, Attachment to Crankshaft 98
Flywheel, Diameter of 96
Flywheel, Functions of 96
Flywheel, Marks on Rims 100
Flywheel, Peripheral Speed of 96
Flywheel, Simplest Type 98
Flywheel, Use in Oil Circulation 223
Forced Circulation Methods .. 241
Forced Circulation System, Parts of 242
Four-Cycle Engine, Advantages 47
Four Cylinder Engine Ignition 196
Four Point Support 102
Four Speed Gearset 299
Four Stroke Cycle Gas Engine 41
Four Wheel Drive, Gearset for 314
Four Wheel Drive System ... 314
Four Wheel Drive, Wheel for 317
Frame, Armored Wood 342
Frame, Cambered Side Members 343
Frame, Construction of 345
Frame, Function of 341
Frame Parts, Lubrication of.. 477
Frame, Pressed Steel 342
Frame Side Member, Repairing 534
Frame, Underslung 344
Frame, Upswept Side Members 343
Frames, Materials of Construction 341
Frames, Use of Wood in 341
Front Axle, Caster Construction 366
Front Axle Construction 363
Front Axle, I Beam Form ... 364
Front Axle, Troubles with 540
Front Wheel Bearings 366
Friction Change Speed Gearing 274
Friction Drive Axle, Action of 280
Friction Gear, Applied to Rear Axle 278
Friction Gear, Driving Member 275
Friction Gear for Large Power 277
Friction Gear, Limitations of . 276
Friction Gearing, Parts of ... 274
Friction Gearing, Speed Changes with..... 275
Friction Gearset Control 435
Friction of Bearings 412
Friction Transmission Trouble 525
Friction, What It Is 210
Fuel Injection System 119
Fuel Supply System Faults .. 488
Fuels for Automobile Power Plant 105
Fuels, Liquid 105
Full Elliptic Springs 348
Full Floating Axle 332
Function of Clutch Pedal 440
Function of Radiator 248
Function of Sub-frame 345
Function of Valves 58
Functions of Automobile Parts. 30
Functions of Flywheel 96
Functions of Induction Coil .. 155
Functions of Manifolds 100
Functions of Radius Rods 354
Functions of Vibrator 156

G.

Gas Engine, Comparison with Steam 37
Gas Engine Crankshafts 90
Gas Engine Cylinder Lubrication 212
Gas Engine, Diesel System ... 118
Gas Engine, Four Stroke Cycle 41
Gas Engine, Long Stroke 89
Gas Engine, Main Elements of 39
Gas Engine, Operating Principle of 37
Gas Engine, Two Stroke Cycle 39
Gas Engines, Cylinders for .. 54
Gas Engines, Five or Seven Cylinder 53
Gas Engines, Knight Type ... 65
Gas Engines, Multiple Cylinder 49, 585
Gas Engines, Eight and Twelve Cylinder 586
Gas Engines, Number of Cylinders Used 49
Gas Engines, Parts of 54
Gas Engines, Weight per Horsepower 53
Gas Power, Advantages of ... 18
Gas Supply to Cylinders 38
Gasoline as Fuel 106
Gasoline, Chemical Composition of 115
Gasoline Motor, How to Crank 428
Gasoline Proportion, How Regulated 131
Gear Drive, Advantages of ... 313
Gear Pump, Action of 245
Gearing, Differential 321
Gearing, Friction 274
Gearshift, Electric 444
Generators, Electric 630
Generator Regulation 634
Gradient Resistance 34
Groves in Cylinder, Cause of .. 501

H.

Heat Loss in Cooling System . 233
Heating, Due to Defective Lubrication 520
Hele-Shaw Clutch 268
High Tension Magneto, Advantages of 177
High Tension Magneto, Principal Types of 179
High Tension Systems 195
Hissing, Cause of 489
Hot Head Ignition 142
Hot Tube Ignition 141
Hottest Portion of Cylinder .. 231
How Automobile Parts are Lubricated 217
How Dry Cells are Used 167
How Gas is Exploded 141
How Gas is Silenced 140
How to Crank Motor 428
How to Prime Engine 429
How to Remove Valves 495
How to Tickle Carburetor 428
Hydraulic Brake 606

I.

I Beam Axle 364
Igniter Plate for Low Tension Spark 192
Ignition by Distribution System 197
Ignition by Double System ... 203
Ignition by Electricity 143
Ignition by Hot Head 142
Ignition by Hot Tube 141
Ignition by Master Vibrator System 199
Ignition by Open Flame 141
Ignition by Transformer Coil System 201
Ignition by True High Tension Magneto 199
Ignition by Two-point System 206
Ignition by Unisparker System 205

Ignition System Faults, How to Detect 487
Ignition System for Four Cylinder Engine 196
Ignition System Troubles 503
Ignition Systems, Principal Parts of 147
Individual Clutch Change Speed Gear 287
Individual Clutch Gear, Construction of 288
Individual Clutch Gear, Silent Chain Type 289
Individual Clutch Gearset Control 444
Individual Cylinders 58
Individual Coil Action 158
Induction Coil, Functions of.. 155
Induction Coil Parts 155
Induction Coil Troubles 507
Inlet and Exhaust Cams 78
Inlet Manifold Trouble 515
Inlet Stroke, Actual Duration of 71
Inner Tube, How to Remove .. 557
Installing Anti-friction Bearings 419
Insufficient Lubrication, Signs of 480
Internal Brakes 452
Internal Combustion, definition of 38
Internal Planetary Gearing ... 284
Irreversible Steering Gear ... 360
Improvements in Design 583

K.

Kerosene as Fuel 108
Kerosene Vaporizer, Action of 136
Kerosene Vaporizer for Two-cycle Engine 139
Knocking Noise, Cause of 489

L.

Laminated Wood Frame 342
Leaf Springs 347
Leather Universal Joints 619
Lighting Automobiles, Methods of 565
Limitation of Friction Gear .. 270
Liquid Fuels, Alcohol 110
Liquid Fuel, Benzol 109
Liquid Fuels, Best Storage System 113
Liquid Fuels, Gasoline 106
Liquid Fuels, How Carried in Automobiles 113
Liquid Fuels, Kerosene 108
Load, Angular 407
Load, Radial 407
Load, Thrust 407
Loads Imposed on Bearings .. 407
Location of Change Speed Gears 301
Lock for Differential Gears .. 328
Logical Steering Wheel Position 456
Long Stroke Gas Engine 89
Loose Bearings, How to Detect 516
Lost Power, Causes of 494
Low Grade Fuels, How Utilized 134
Low Tension, Igniter Plate, Construction of 192
Low Tension Ignition, Advantages of 194
Low Tension Ignition Systems 189
Low Tension Magneto, Why Timed 104
Low Tension Spark Coil 191
Low Tension Spark, How Timed 189
Lubricant, Effect of Acid in... 213
Lubricant for Ball Bearings .. 423
Lubricant for Cylinder 212
Lubricant for Engine 465
Lubricant, Testing for Acid .. 213

Lubricants, Best for Automobile Use 212
Lubricants, Cold Test of 215
Lubricants, Derivation of 211
Lubricants, Fire Test of 215
Lubricants, Flash Test of 214
Lubricants, How to Detect Adulterants 216
Lubricants, Organic 473
Lubricants, Viscosity of 213
Lubricants, Where Oil is Used 211
Lubricants, Where Only Greases are Used 211
Lubricants, Wood or Cork Filled 473
Lubricating Sliding Gearset .. 471
Lubricating System, Typical .. 227
Lubricating by Constant Level Splash System 221
Lubrication by Mechanical Oilers 219
Lubrication by Pressure Feed . 218
Lubrication by Sight Feed ... 218
Lubrication, Cold Weather ... 685
Lubrication, Definition of 210
Lubrication, Instructions for Chalmers 482
Lubrication, Instructions for Packard 484
Lubrication of Automobile Parts 217
Lubrication of Clutch 470
Lubrication of Drive Chains .. 473
Lubrication of Engine Exterior Parts 467
Lubrication of Engine Interior 466
Lubrication of Fan 469
Lubrication of Frame Parts .. 477
Lubrication of Front Axle 476
Lubrication of Pump 469
Lubrication of Rear Axle 474
Lubrication of Springs 478
Lubrication of Timer 470
Lubrication of Universal Joints 474
Lubrication, Why Necessary .. 210

M.

Magneto Armatures, Speed of 183
Magneto Breaker Box, Functions of 180
Magneto Condenser, How Used 180
Magneto Distributor, Functions of 179
Magneto Drives 185
Magneto Faults, How to Remedy 509
Magneto for Two-point Ignition 208
Magneto, High Tension 177
Magneto, Low Tension 177
Magneto, Lubrication of 469
Magneto Spark Gap, Why needed 180
Magneto, Types of 176
Main Bearings, Crankshaft ... 94
Main Defects of Mechanical Oilers 518
Main Defects of Pump Circulating System 519
Main Elements of Gas Engine 39
Making a Gradual Stop 458
Manifold Design 100
Manifold, Functions of 100
Master Vibrator System 199
Materials to Face Con Clutch . 260
Materials Used in Brakes 453
Materials Used in Connecting Rods 86
Materials Used in Multiple Disc Clutches 270
McCue Wire Wheel 371
Mechanical Generators, Action of 175
Mechanical Engine Starters .. 622
Mechanical Oiler, Defects of .. 518
Methods of Driving Dynamos . 187
Methods of Driving Magneto . 185
Methods of Producing Electricity 164
Mixing Chamber Troubles 515

Mixing Valve, Simple 121
Mixture, How to Detect Defects 131
Motor Starter, Air System ... 620
Motor Starters, Automatic ... 619
Motor Starters, Electric 624
Motor and Generator Faults .. 678
Muffler Cut-out, Function of .. 140
Muffler, Functions of 139
Multiple-Disc Clutch, Construction of 267
Multiple-Disc Clutch, Features of 269
Multiple-Disc Clutch, Hele-Shaw Design 268
Multiple-Disc Clutch, Materials Used in 270
Multiple Connection for Cells . 168
Multiple Cylinder Engines ... 49
Mutiple Jet Carburetor 129
Multiple-Series Connection ... 168
Mushroom Valves, Forms of .. 62

N.

Noisy Exhaust, Cause of 489
Noisy Operation of Engine ... 515
Noisy Operation of Planetary Gear 528
Noisy Operation of Sliding Gear 528
Non-Freezing Solutions 684
Number of Main Bearings on Crankshafts 94

O.

Oil Circulation by Flywheel .. 223
Oil Circulation by Pump 222
Oil Supply to Crankcase in Emergencies 230
Oil Supply to Engines, Why Regulated 224
One Unit System 626
Open and Closed Circuits 148
Open Frame Ignition 141
Operating Principle of Gas Engine 37
Outer Casings, Life of 394
Overheating, Causes of 519
Overhead Camshaft 595
Overlubrication, How to Detect 480
Oxygen for Supporting Combustion 115

P.

Palmer Cord Tire 390
Parts of Automobile Power Plant 27
Parts of Friction Gearing 274
Parts of Induction Coil 155
Parts of Planetary Gearset ... 282
Parts of Spark Plugs 154
Parts of Storage Battery 171
Passing Other Vehicles 461
Peripheral Speed, Definition of 96
Peripheral Speed, Safe 96
Permissible Temperature of Air Cooled Engine 233
Piston and Ring Valves 67
Piston Bosses 83
Piston, Function of 83
Piston Ring Removal 499
Piston Ring Troubles 499
Piston Rings 83
Piston Rings, Common Forms of 84
Piston Rings, Why Split 84
Piston, Size of 85
Piston Speed, Definition of ... 39
Planetary Change Speed Gearing 281
Planetary Gearing, Internal Type 284
Planetary Gearset, Adjusting Brake Bands 528
Planetary Gearset Control 433
Planetary Gearset High Speed Slipping 526
Panetary Gearset, Noisy Operation 528
Planetary Gearset, Obtaining Speed Changes with 283

Planetary Gearset, Oiling 471
Planetary Gearset, Typical ... 282
Platform Springs 348
Pneumatic Tires 388
Pneumatic Tires, Outfit for Care of 545
Pneumatic Tires, Rules for Care of 563
Pneumatic Tires, Sizes of 395
Pneumatic Tires, Troubles with 549
Pneumatic Tire Construction . 390
Pneumatic Tire, Inflation Pressures of 395
Pneumatic Tire, Inner Tube .. 393
Pneumatic Tire, Palmer Cord . 390
Pneumatic Tire, Rough Tread . 393
Pneumatic Tire, Smooth Tread 393
Poor Gear Shifting, Cause of . 491
Positive Drive Differential ... 607
Power Needed for Automobiles 35
Power, Proportion to Weight . 35
Power Transmission by Skew Bevel Gear 314
Power Transmission, Direct Drive Method 307
Power Transmission, Double Reduction 307
Power Transmission, Four Wheel Drive 314
Power Transmission Systems . 304
Power Transmission Systems, Efficiency of 313
Power Transmission, Universal Joints for 313
Power Transmission, Worm Drive 307
Pressed Steel Frame 342
Pressure Feed Defects 514
Pressure Feed Lubricator 218
Pressure Feed Oiler 517
Primary Battery Action 164
Principal Parts of Ignition System 147
Principal Types of Automobiles 17
Principal Valve Defects 497
Principles of Induction Coil Action 158
Principle of Clutch Action ... 257
Principal of Muffler Action ... 140
Progressive Sliding Gearset .. 293
Process of Valve Grinding ... 497
Pump Bearings, How Oiled .. 469
Pump Circulation of Oil 222
Pumps for Circulating Water . 243
Pumps for Oil Circulation ... 224
Punctures, Causes of 549
Punctures, How to Repair 550
Puncture Proof Tires 398
Puncture, Sealing with Cemented Patch 553

Q.

Quadrants, Selective Types .. 442
Quick Detachable Rim 378

R.

Radial Load 407
Radiating Surface of Cylinder 235
Radiator, Function of 248
Radiators, Efficiency of 248
Radiators, Types of 248
Radius Rod, Wear in Anchorage 544
Radius Rods, Functions of ... 354
Rattling, Cause of 490
Rear Axle, Dead Type 329
Rear Axle Friction Gear 278
Rear Axle, Live Type 330
Rear Axle Lubrication 474
Regulating Gasoline Proportions 131
Regulating Oil Supply to Engine 227
Removal of Carbon Deposits . 502
Removal of Piston Rings 499
Removing Inner Tube 557
Repairing Loose Bearings 517
Repairing Piston Rings 500

Repairing Steering System ... 539
Requirements of Clutch 271
Resistance, Air 33
Resistance of Grades 34
Resistance, Traction 34
Rim, Bolted On 379
Rim, Clincher 377
Rim Cutting, Causes of 556
Rim, Demountable 379
Rim ,Quick Det..chable 378
Rings for Pistons 83
Road Rules 456
Roller Bearings 404
Roller Bearings, American ... 419
Roller Bearings, Solid or Flexible 410
Roller Chain 311
Rotary Valves 67
Rough Tread Casings 393
Rusted Casings, How to Remove 559

S.

Safe Driving Speeds 457
Safe Peripheral Speed 96
Sagging Frame Member, Repairing 534
Scraping-in Bearings 403
Scratches in Cylinder, Cause of 501
Secondary Battery Action 165
Secondary Winding, Why Used 157
Sectional Block Tire 382
Selective Gearset, Advantages of 297
Selective Gearset Control 439
Selective Gearset, Four Speed 299
Selective Sliding Gearset 295
Semi-Elliptic Springs 348
Semi-Elliptic Springs, Advantages of 349
Semi-Flating Axle 332
Series Connection 168
Set Spark, How Used 146
Shaft Drive System Troubles . 532
Shock Absorbers, Types of ... 573
Sight Feed Lubricator 218
Silencing Exhaust Gas 140
Silent Chain Gearbox 289
Silent Type Drive Chain 312
Simple Battery Ignition System, Parts of 149
Simple High Tension Ignition Group 195
Size of Dry Cells 169
Sizes of Valves 62
Skew Bevel Gear Drive 314
Skipping, Causes of 503
Sliding Gear Car, How to Start 441
Sliding Gear Control System .. 439
Sliding Car, Noisy Operations of 528
Sliding Gears, Will Not Engage 530
Sliding Gearset Control 436
Sliding Gearsets, Types of ... 291
Slipping Clutch 521
Smooth Tread Tire 393
Soft Metal Bearings, Advantages of 401
Solid Dual Tire 381
Solid Tires 381
Spare Parts for Repairs 577
Spark, Why Advanced 145
Spark, Why Retarded 145
Spark Coil for Low Tension Spark 191
Spark Gap, Why Needed 180
Spark, How Produced in Cylinder 144
Spark Lever, Best Position for 432
Spark Plug Faults 506
Spark Plugs, Air Gap 154
Spark Plugs, How Used 153
Spark Plugs, Parts of 154
Spark Plugs, Types of 153
Specifications of Cylinder Oil . 217
Speed Governor, Automatic .. 431
Speed Indicators, Value of 571

Speed of Magneto Armature Rotation 183
Spraying Carburetor 121
Spring Blocks, Movable 352
Spring, Platform Suspension . 348
Spring Suspension, Conventional 349
Springs, Common Types 346
Springs, Compound 350
Springs, Emergency Road Repair 536
Springs for Valves 81
Springless Valve Designs 595
Springs, Full Elliptic 348
Springs, How Attached to Axle 352
Springs, How Secured to Axle 366
Springs, Leaf 347
Springs, Lubrication of 478
Springs, Obtaining Strength and Flexibility 351
Springs, Repair of 535
Springs, Rusty 535
Springs, Semi-Elliptic 348
Springs, Three-quarter Elliptic 348
Spur Differential Gear 323
Squeak, Cause of 489
Standard Selective Quadrants . 442
Starting Automobile Power Plant 425
Starters for Engines 619
Starting Motors, How Connected 639
Starting Sliding Gear Car ... 441
Starting System Troubles 671
Steam Power for Automobiles 17
Steering, Direct Leverage System 359
Steering Gear, Back Lash in .. 537
Steering Gear, Irreversible ... 360
Steering Gear, Reduction System 359
Steering Gear, Stiff Action ... 537
Steering Gear, Thread and Nut 361
Steering Gear, Worm Reduction 361
Steering Gears, How Oiled ... 476
Steering Gears, Taking up Wear in 537
Steering Knuckle, Elliot 365
Steering Knuckle, Mercedes .. 365
Steering Knuckles, Types of .. 365
Steering System, Complete for Automobiles 357
Steering System, Lost Motion in 539
Steering System, Repairing .. 539
Steering the Automobile 355
Stering Wheel Position, Logical 456
Stepney Emergency Rim 572
Stewart Vacuum Fuel Feed .. 607
Stiff Action of Steering Gear . 537
Stone Bruises, Causes of 556
Stopping Gradually 458
Storage Batteries, How Measured 162
Storage Battery, Capacity of . 171
Storage Battery Construction . 169
Storage Battery Parts 171
Storage Battery Care 669
Straight Roll Bearings 410
Stripped Gears, Cause of 531
Stroke, Limits to Length of .. 89
Stroke, Relation to Bore 89
Sub-frame, Function of 345
Sudden Vehicle Stop, Causes of 487
Switch, Construction of 151
Switch, Lighting 636
Switch, What It Does 151
Switch-starting 636

T.

Taking Up Lost Motion in Steering Gear 537
Test Coil Current Consumption 163

Testing Storage Batteries 669
Testing Compression 494
Testing Valve Seating 490
Thermo-Syphon System 240
Thread and Nut Steering Gear 361
Three Port Two-cycle Engine . 44
Three Plate Clutch, Materials Used in 265
Three Point Support 102
Three-quarter Elliptic Spring . 348
Thrust Loads 407
Tickling Carburetor, Method of 428
Tie-bars, Use of 357
Timer, Construction of 150
Timers, Types of 160
Timing Marks on Flywheels .. 100
Tire Chains, Value of..... 571
Tire Lugs, Where Used 394
Tire, Pneumatic 388
Tire Protectors, How Made .. 561
Tire Troubles, Cuts in Casings 557
Tire Troubles, Rim Cutting .. 556
Tire Troubles, Stone Bruises .. 556
Tire Troubles, Weak Casings . 556
Tire Troubles, Worn Threads . 556
Tires, Airless ..t..... 387
Tires, Cushion 386
Tires, Puncture Proof 398
Tires, Solid 381
Tires, Solid Dual 381
Tool Equipment for Automobiles 575
Torpedo and Stream Line Bodies 33
Torque, Definition of 352
Torque Stresses, How Resisted 353
Transformer Coil Magneto System 201
Traction Resistance, Effect of 34
Troubles of Ignition System .. 503
Troubles with Differential Gearing 533
Troubles in Starting Systems . 671
Troubles in Lighting Systems . 674
True High Tension Magneto System 199
Tubular Axle 363
Two-Cycle Engine, Advantages of 43
Two-Cycle Engine, Differential Piston 45
Two-Cycle Engine Three Port 44
Two-Cycle Engine, Two Port . 44
Two-Cycle Motors, Disadvantages of 45
Two Port Two-Cycle Engine .. 44
Two-Point Ignition System ... 206
Two-Point Magneto System .. 208
Two-Speed Direct Drive Axle . 337
Two-Stroke Cycle Gas Engine 39
Two Unit System 621
Types of Magneto 176
Types of Springs 346
Types of Steering Knuckle ... 365
Typical Dynamo, Action of .. 176
Typical Lubricating System .. 227

U.

Underslung Frame 344
"Unisparker" System of Ignition 205
Unit Power Plant 102
Units of Electrical Measurement 161
Universal Joints, Lubrication of 474
Universal Joints, Wear in 532
Universal Joints, Why Used .. 313
Upswept Frame Members 343
Useful Accessories 582
Using Dry Cells 167
Using Engine as Brake 464
Using Low Grade Fuels 134
Utility of Change Speed Gearing 272

V.

Vacuum Fuel Feed 598
Valve Chamber, Use of 56

Valve Grinding Process Outlined 497
Valve Lag, Explaining 73
Valve Plunger, Best Form of . 80
Valve Removal, Process of ... 495
Valve Springs, Strength of ... 83
Valve Systems, Defects of 503
Valve Timing 70
Valve Timing, Conventional Method 73
Valve Troubles, How to Detect 559
Valves, Determining Size of .. 62
Valves, Forms of Mushroom .. 62
Valves, Function of 58
Valves, Knight Sliding Sleeve 65
Valves, Opening and Closing of 70
Valves, Operation of 60
Valves, Piston and Ring 67
Valves, Placing of 60
Valves, Rotary 67
Valves, Springs for 81
Valves, Springless 595
Variable Ignition, Why Necessary 144
Venturi Tube Carburetor 126
Vibrator, Functions of 156
Viscosity, Definition of 213
Vulcan Electric Gearshaft ... 444
Vulcanizers, Portable 550
Vulcanizing, Acid Cure 553
Vulcanizing, Hot Process 550

W.

Warning Signals 570
Water Circulating Pumps 243
Water Cooling by Thermo-Syphon System 240
Water Cooling, Common Method 240
Water Cooling, System of 240
Water Jacket, Use of 56
Wheel Artillery 367
Wheel, Cast Steel 368
Wheel for Four Wheel Drive . 317
Wheel Rim 377
Wheels for Automobiles 367
Wheels, How Moved for Steering 357
Wheels, Lubrication of 476
Wheels, Method of Drive 333
Wheels, Spring 376
Wheels, Wire Spoke Type ... 369
White Smoke at Exhaust 132
Wind Shield, Utility of 572
Wire Spoke Wheels 369
Wire Wheel Advantages 371
Wire Wheel Construction 372
Wire Wheel, Detachable 373
Wire Wheels, McCue 371
Wire Wheels, Rudge-Whitworth 374
Wiring Dry Batteries 168
Wiring, Troubles in 676
Wood Frame, Laminated 342
Wood Frames 341
Worm Drive Gear 307
Worm Reduction Steering Gear 361
Why Clutch is Needed 256
Why Cylinder is Cooled 231
Wristpin, How Secured 85
Wristpin, Why Used 85

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INDEX

	PAGES
Air Brakes	25, 28
Arithmetic	16, 29, 36
Automobile Books	3, 4, 5, 6
Automobile Charts	6, 7
Automobile Ignition Systems	5
Automobile Lighting	5
Automobile Questions and Answers	4
Automobile Repairing	4
Automobile Starting Systems	5
Automobile Trouble Charts	6, 7
Automobile Welding	5
Aviation	7
Aviation Chart	7
Batteries, Storage	5
Bevel Gear	22
Boiler-Room Chart	10
Brazing	8
Cams	22
Carburetion Trouble Chart	9
Change Gear	22
Charts	8, 9, 10
Coal	25
Coke	11
Combustion	25
Compressed Air	11
Concrete	11, 12, 13
Concrete for Farm Use	13
Concrete for Shop Use	13
Cosmetics	32
Cyclecars	6
Dictionary	14
Dies	14, 15
Drawing	15, 16
Drawing for Plumbers	33
Drop Forging	15
Dynamo Building	16
Electric Bells	16
Electric Switchboards	15, 18
Electric Toy Making	17
Electric Wiring	17, 18, 19
Electricity	16, 17, 18, 19, 20
Encyclopedia	28
E-T Air Brake	28
Every-day Engineering	40
Factory Management	20
Ford Automobile	3
Ford Trouble Chart	7
Formulas and Recipes	34
Fuel	20
Gas Construction	22
Gas Engines	21, 22
Gas Tractor	38
Gearing and Cams	22
Glossary of Aviation Terms	8, 14
Heating	37
Horse-Power Chart	10
Hot-Water Heating	37
House Wiring	18, 19
How to Run an Automobile	5
Hydraulics	23
Ice and Refrigeration	23
Ignition Systems	5
Ignition-Trouble Chart	7
India Rubber	35
Interchangeable Manufacturing	28
Inventions	23
Knots	24
Lathe Work	24
Link Motions	26
Liquid Air	25
Locomotive Boilers	26
Locomotive Breakdowns	26
Locomotive Engineering	25, 26, 27, 28
Machinist Book	28, 29, 30
Magazine, Mechanical	40
Manual Training	30
Marine Engineering	31
Marine Gasoline Engines	22
Mechanical Drawing	15, 16
Mechanical Magazine	40
Mechanical Movements	29
Metal Work	14, 15
Motorcycles	6, 7
Patents	23
Pattern Making	32
Perfumery	32
Perspective	15
Plumbing	33, 34
Producer Gas	22
Punches	14
Questions and Answers on Automobile	4
Questions on Heating	37
Railroad Accidents	27
Railroad Charts	10
Recipe Book	34
Refrigeration	23
Repairing Automobiles	4
Rope Work	24
Rubber	35
Rubber Stamps	35
Saw Filing	35
Saws, Management of	35
Sheet-Metal Works	14, 15
Shop Construction	20
Shop Management	20
Shop Practice	20
Shop Tools	29
Sketching Paper	16
Soldering	8
Splices and Rope Work	24
Steam Engineering	35, 36
Steam Heating	37
Steel	37, 38
Storage Batteries	5
Submarine Chart	10
Switchboards	17, 18
Tapers	24
Telegraphy, Wireless	20
Telephone	19
Thread Cutting	28
Tool Making	28
Toy Making	17
Train Rules	27
Tractive Power Chart	10
Tractor, Gas	38
Turbines	38
Vacuum Heating	37
Valve Setting	26
Ventilation	37
Watch Making	39
Waterproofing	13
Welding with Oxy-acetylene Flame	39
Wireless Telegraphy	20
Wiring	17, 18
Wiring Diagrams	17

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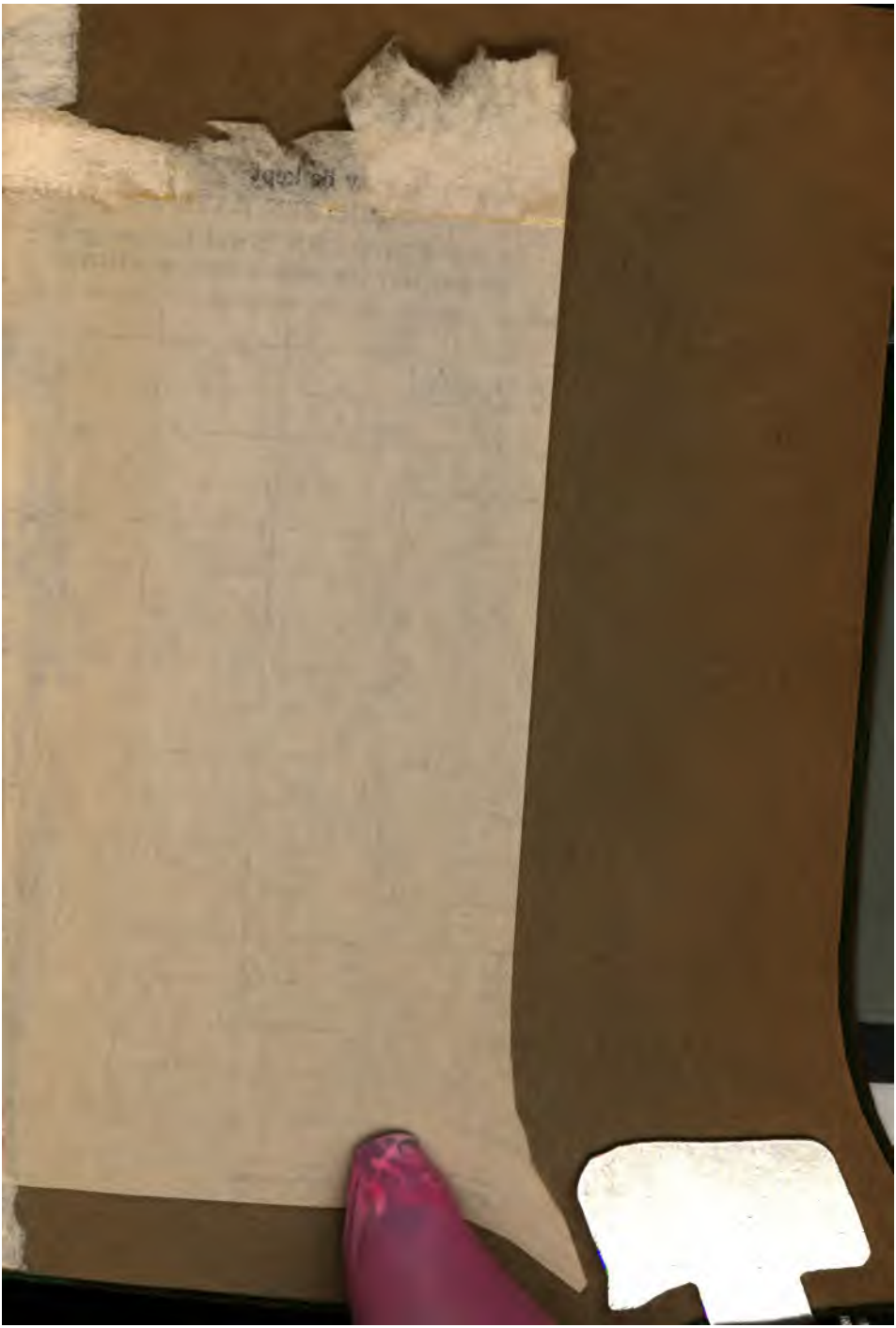

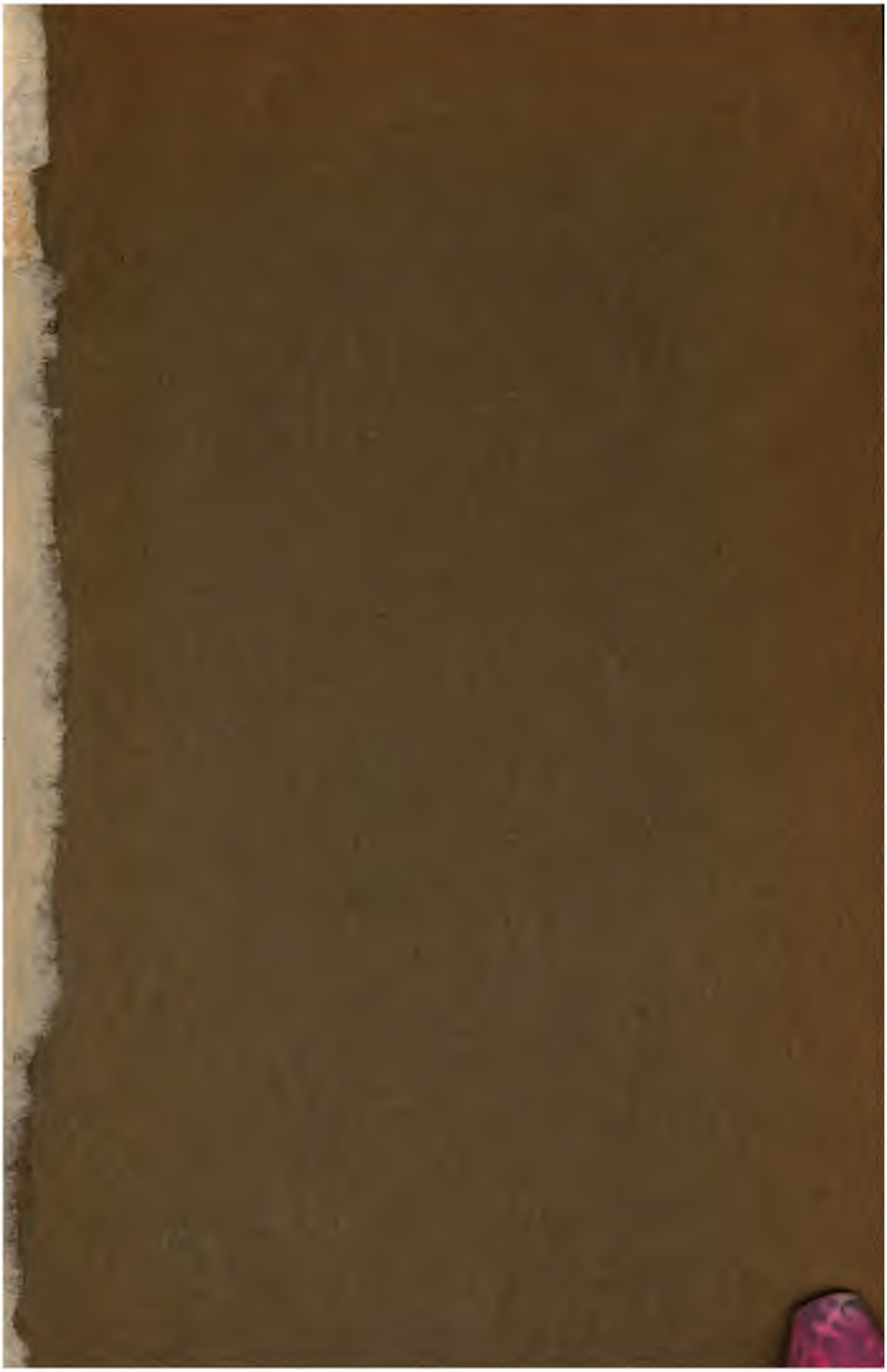

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